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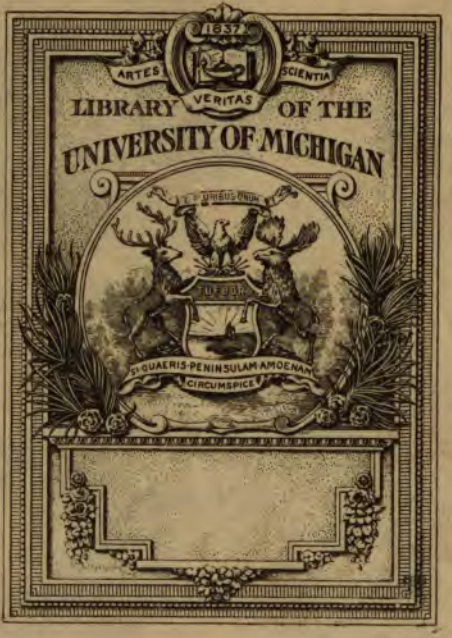
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STUDIES IN

MICROSCOPICAL SCIENCE,

EDITED BY

ARTHUR C. COLE, F.R.M.S.

VOL. I.

WITH FIFTY-THREE LITHOGRAPHED PLATES.

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820.

PREFACE.

The illustrations in this volume have been drawn on stone by Mr. JAMES W. WATSON, of Birmingham, from original drawings by Mr. J. E ADY. A few of the figures have been copied from other works; in each such instance, however, the source is acknowledged.

All the articles, with the exception of three, have been written by Mr. ADY.

The excellence of the microscopical preparations which have been issued with this work, is due to the skill of Mr. MARTIN J. COLE.

The Editor is indebted to PROFESSOR HEDDLE for the articles on the red and white Syenites, of Lairg, and the serpentine of Portsoy. He desires to thank the following gentlemen for valuable assistance, advice and suggestions:—PROFESSORS NICHOLSON, HEDDLE, BALFOUR, DALLINGER, and Messrs. WRIGHT WILSON, BLACKETT, CRISP, STEWART, HOGG, HAMPTON, THORP, and MUNRO.

LONDON,
May, 1883.

Julian 07.1.5.90.

YELLOW FIBRO-CARTILAGE.

L.V.S. Pinna of Ear of Cow × 333.
Double Stained in Logwood and Eosin.

Etymology.—Fi'bro-Car'ti-lage, from Fibre and Cartilage. Fibre or Fiber, n. [Fr. *fibre*, from Lat. *fibra*; Pr., Pg., and It. *fibra*, Sp. *fibra*, *hebra*]. A delicate thread-like or string-like substance, of which the tissues of living things are in part composed.

Cartilage, n. [Fr. *Cartilage*, Lat. *Cartilago*]. *Anatomy*,—One of the connective tissues (Reichert) found in the animal body. It consists of cells imbedded in a whitish, translucent, elastic, fibrillated, or apparently homogeneous matrix. The cells secrete the matrix, or intercellular substance, and the texture thus constituted forms one of the most important tissues in the bodily economy. It may be seen forming a kind of skeleton in the *Medusæ*, where the cells are large, of regular shape, and the structure exhibits but a scanty amount of intercellular substance. The shape and position of the cells, the varying proportion of the intercellular substance, and the minute changes which both of these elements undergo, form the basis upon which the most rational classification of cartilage has been founded. Before we leave the *Invertebrata*, we find this tissue very curiously developed in the *Cephalopoda*, where the cells throw out radiating processes which unite with those of subjacent cells, and form a structure similar to, but even more highly developed than, the cartilage of some of the Elasmobranch fishes *(Selachii)*.

Cartilage forms the entire permanent skeleton of many of the higher animals *(Elasmobranchii)*, whilst in others it constitutes a varying proportion of that structure, which ultimately in the highest vertebrates persists only in such situations as the articular ends of the bones between the ribs and sternum, the walls of the trachea and bronchi, the larynx, the intervertebral discs, sacro-iliac synchondrosis, symphysis pubis, interarticular situations, glenoid and cotyloid ligaments, the grooves for tendons, the ear, and in all parts where a decidedly firm yet less yielding structure than bone is required. In all other parts it becomes eventually replaced by bone, and in certain pathological conditions *(Enchondromata)* invades other parts of the body.

Description.

The differentiation of the matrix of cartilage forms the chief item in its most modern classification, which, in the higher *vertebrata*, recognises it as *hyaline*, *white fibro*, and *yellow fibro-cartilage*. It is with the last of these that we are at present concerned.

The specimen we have selected for our illustration is a longitudinal vertical section of the pinna of the ear of the cow, which has been stained with logwood and eosin. It will be observed that the re-agents have acted upon the tissues in a most remarkably selective manner; the cartilage has been stained a beautiful purple hue by the logwood, the eosin has acted upon the surrounding structures, staining the protoplasm and nuclei of the cartilage cells, the perichondrium, connective tissue, muscular fibres, and skin, of a reddish colour, whilst the hairs and sebaceous glands have resisted the action of both of the dyes. The cartilage affords a most typical example of the yellow fibrous variety.

Yellow fibro-cartilage has many synonyms, amongst which the more appropriate are *reticular*, *spongy*, and *elastic* cartilage. It consists of cells imbedded in a matrix of yellowish colour, and strongly defined fibrous texture. It is more flexible and elastic than either hyaline or white fibro-cartilage, and the fibres in the matrix have all the characters of the fibres of elastic tissue. It occurs most typically in the pinna of the ear and eustachian tube, in the epiglottis, and corniculæ laryngis. If a section of the arytenoid cartilage be made in the direction of, and through the cornicula laryngis, the hyaline cartilage of the former is seen to merge gradually into the elastic cartilage of the latter. A section such as this, examined with a magnifying power of 300 diameters, shows very clearly that a structural change has taken place in the hyaline matrix, and given rise to a network of elastic fibres, amongst which the cartilage cells appear.

The Cells in the pinna of the cow's ear are of an ellipsoidal shape, and of an average size of 1-1800th in. through the major, and 1-2250th in. through the minor axis. A measurement of the sizes of the cells in the pinna of the ear and in the epiglottis of the cow, sheep, dog, cat, rabbit, pig, and human subject has shown us that they vary very considerably in their dimensions, even in the same piece of tissue, so that we are warranted in assigning very little value to this item.

An examination with a power of about 300 diameters, enables us to make out the following features:—The cells are seen to be ovoid in form, and surrounded by a meshwork of fibres. Towards the periphery of the cartilage they are more numerous, somewhat flattened in contour, and a relatively larger number of the cells seem to be undergoing division.

In most of the cells the nuclei are plainly visible.

By substituting a power of 800 diameters, the following additional characters may be recognised:—The central cells are seen to be surrounded by a thin lamella of hyaline matrix; in a few cases a distinct capsule may be seen around some of the cells, especially those undergoing division, and two kinds of nuclei may be detected; one, a smooth nucleus containing a nucleolus, the other (sometimes occurring in pairs) of a granular aspect without nucleoli. In the stained specimen the protoplasm of the cells may occasionally be seen shrunk from the cell-wall without sign of laceration around the nucleus, in which instance the capsular nature of the cell-wall is rendered apparent, and its origin as a *secretion* of the protoplasm demonstrated.

THE MATRIX multiplied 300 diameters exhibits a close meshwork of fibres with interstitial hyaline substance; this latter is more clearly seen in the vicinity of the peripheric cells. The fibres are branched, refract light strongly, and in all respects closely resemble those of elastic connective tissue.

A power of 800 diameters reveals a hyaline matrix immediately around all the cells, and, to some extent, between the fibres of the matrix. Many of the fibres are seen to be cut transversely, and thereby give the tissue a granular spongy aspect. A careful examination of the fibres shows them to be in direct continuity with the fibres of the perichondrium, where they appear as fine elastic fibres.

No systems of blood-vessels or nerves have been discovered in cartilage of any sort. Its nutrition must therefore depend upon its porosity, which is sufficient to permit of the irrigation of its elements by the penetration of lymph from the neighbouring vessels. Occasionally blood-vessels are found in cartilage, chiefly of the hyaline variety, when they appear in peculiar dendritic forms, and as RANVIER* has shown, only as a preliminary to ossification.

Yellow fibro-cartilage is preceded in the embryo by hyaline cartilage. A study of its development shows that the elastic fibres appear in the matrix often at a distance from the cells, and they are doubtless produced by the coalescence of minute particles of elastic substance which result from the metabolism of chondrogen.**

THE ACTION OF REAGENTS.—If a thin section of the elastic fibro-cartilage of the external ear of the cow be examined under a magnifying power of about 800 diameters, and acted upon by various reagents, the following details may be learned concerning it, which the mere inspection of a mounted preparation cannot reveal.

WATER, and many staining reagents cause a shrinkage of the protoplasm without laceration around the nuclei of the cells. From this we learn that the capsular cell-wall, which may become apparent, is a secretion of the protoplasm, and not a mere modification of its periphery. Most of the staining reagents act upon the protoplasm of the cells more markedly than upon the matrix, and bring the nuclei and nucleoli into view more distinctly.

ACETIC ACID and CAUSTIC ALKALI render the nuclei and nucleoli distinct by causing the protoplasm of the cells to become hyaline. Their reaction on the matrix will be noted below.

GOLD-CHLORIDE is a valuable reagent in the study of cartilage. It dyes the cells violet without causing the protoplasm to shrink.

OSMIC ACID reveals the presence of fatty particles in the cells, by rendering them black, it also darkens the whole tissue slightly.

IODINE stains the protoplasm of the cells a pale yellow colour, the nucleus somewhat more deeply, and indicates the presence of small

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* L. RANVIER, *Traité Technique d' Histologie* Paris, 1875, p. 290.

** H. MULLER, *Verhandlungen der physikal-medicin*, Gesellschaft zu Würzburg, x. p. 132.

particles of glycogen in the protoplasm by turning them a rich brown colour.

Prolonged boiling of the matrix of hyaline cartilage in water gives rise to an albuminoid substance allied to gelatine and termed *chondrin* (C 49·9, H 6·6, N 14·5, SO·4, O 28·6 per cent.), but as chondrin is readily soluble in hot water, and the matrix of the cartilage is not, it is supposed to be derived from a hypothetical substance which has been termed *chondrogen*. Yellow fibro-cartilage, when boiled, yields a very small quantity of chondrin and a large amount of another albuminoid, *elastin* (C 55·5, H 7·4, N 16·7, O 20·5, per cent.) Elastin may be easily distinguished from chondrin and gelatine in its property of being quite insoluble in hot water; it still further differs from gelatine by being unaffected by acetic acid, but it may be broken down by the prolonged action of a strong solution of potassium hydrate into granules which dissolve in water.

Methods of Preparation.

The consistency of yellow fibro-cartilage obviates the necessity of any special hardening process to render it suitable for cutting into sections. Where it is desirable to retain the cartilage *in situ*, the tissue may be placed in rectified spirit for twenty-four hours, or, better still, in a saturated solution of picric acid for forty-eight hours. Thus treated, the tissue may be imbedded in a piece of carrot or in paraffin, and either sliced by hand with a sharp razor, or in the well-known microtome of Mr. A. B. Stirling, late sub-curator of the Anatomical Museum of the University of Edinburgh. But by far the best results are obtained by slicing the fresh tissue with the aid of a freezing microtome.*

For purposes of study, the sections of fresh cartilage made with the freezing microtome or cut by hand, should be examined in a 0·75 per cent. sodic chloride solution, or in dilute glycerine with powers of from 300 to 800 diameters. The actions of osmic acid, iodine solution, acetic acid, potassium hydrate, and water, should also be studied on sections of the fresh tissue.

For permanent preparations various staining processes are employed, of which the following are the best :—

Osmic Acid.—Place the sections of *fresh* cartilage in a one per cent. solution of osmic acid for about twenty-four hours, wash in distilled water, and transfer to dilute glycerine for an hour, after which they may be mounted in glycerine or glycerine jelly.†

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*The freezing microtome devised by Professor Rutherford, of the University of Edinburgh, first described by him in the *Journal of Anatomy and Physiology*, May, 1871, and subsequently improved and fully described in his *Outlines of Practical Histology*, 2nd edition, 1876, pp. 164-169, is an instrument of great practical utility, inasmuch as it can be used for cutting unfrozen tissues imbedded in carrot or paraffin, or for cutting them hardened by freezing. But by far the best freezing microtome, as such, is the one invented by Mr. Williams for the Quekett Microscopical Club, and described in the Journal of the Royal Microscopical Society, August, 1881, pp. 697-699. Williams's microtome has been adapted for use with ether as the freezing agent by Mr. J. W. Groves, and we can confidently state that this is the best ether freezing microtome now in use. Both forms are made by Mr. Swift, of Tottenham Court Road, London, W.C

† In all cases where glycerine jelly is used as the preservative medium, it is advisable to steep the specimen in dilute or pure glycerine before hand.

SILVER NITRATE.—The sections of the *fresh* tissue must be well washed in distilled water, for the purpose of removing any chlorides which may be present, and placed in a one-half per cent. solution of silver nitrate for about five minutes, or until they assume a whitish appearance. They should then be washed in ordinary water, and exposed in it or in a weak mixture of alcohol and water to diffuse daylight, until they become brown in colour (due to the precipitation of the silver in form of the black oxide). They may then be mounted in glycerine, glycerine jelly, or Farrants's solution.

GOLD CHLORIDE.—*Perfectly fresh* sections are absolutely necessary in order to ensure success in this beautiful method. The slices are to be placed in a one per cent. solution of chloride of gold for about half-an-hour, thoroughly washed in distilled water and transferred to acidulated water (2 or 3 drops of acetic acid to one ounce of water). Exposure to diffuse daylight for about twenty-four hours reduces the gold, and thereby stains the cartilage violet. The special value of this re-agent depends upon the fact that it dyes the cells of the cartilage without causing any shrinkage of the protoplasm. The sections should be mounted in glycerine, glycerine jelly, or Farrants's solution.

CARMINE, LOGWOOD, EOSIN, and the ANILINE DYES† may be used for staining sections which have been hardened in alcohol. They may be mounted in canada balsam or dammar solution.

DR. FRANCES ELIZABETH HOGAN'S METHOD.

(i.) Steep the sections (fresh or hardened) in alcohol for about five minutes.

(ii.) Transfer to a watch glass full of tincture of steel for two minutes.

(iii.) Remove into a two per cent. solution of pyrogallic acid in alcohol.

When the desired depth of colour has been attained (in one or two minutes), wash the sections in distilled water, and mount them in glycerine, or glycerine jelly. This process imparts a beautifully soft neutral tint to the specimens.

PICROCARMINE* is a reagent which is specially useful for staining sections which have been hardened in picric acid. The cartilage is rendered bright yellow, whilst the perichondrium and subjacent tissues are stained in varying shades of red. The red colour also affects the neuclei of the

† In the Morph : Jahrbuch, vi, 1880, pp. 43-44. DR. M. FLESCH notes that HERMANN has shown that the aniline dyes may be employed to stain the nuclei of tissues exclusively. To do this the sections must be freed from all trace of acids or substances likely to form chemical compounds with other substances, by soaking in distilled water. The sections are to be transferred to an alcoholic solution of the staining reagent for a few seconds, washed in distilled water, and placed in absolute alcohol. As soon as the nuclei are sufficiently stained, they may be mounted in canada balsam or dammar solution.

* See RUTHERFORD, Outlines of Practical Histology. Second Edition. London, 1876, p. 173.

Most of the staining reagents used in microscopical work are excellently prepared and sold by W. MARTINDALE, Pharmaceutical Chemist, 10, New Cavendish Street, Portland Place, London, W.

cartilage cells, which thus appear as so many red spots in the yellow matrix. The sections should be mounted in canada balsam or dammar solution.

Logwood and Picrocarmine.

(i.) Make a strong infusion of logwood chips in tepid water. Add three or four drops of this to a watch glass full of distilled water, and place the sections in it for about fifteen minutes.

(ii.) Wash the sections thoroughly in ordinary water, transfer to acidulated water for a few seconds (30 minims of acetic acid to one pint of distilled water) to get rid of superfluous staining; re-wash thoroughly in ordinary water.

(iii.) Place in rectified spirit* for an hour.

(iv.) Transfer to picrocarmine solution for about three minutes.

(v.) Wash thoroughly in ordinary water and transfer to rectified spirit. Mount in canada balsam or dammar solution.

Logwood and Eosin.—Follow the first three processes indicated in the preceding method.

(iv.) Transfer to an alcoholic solution of eosin (three grains of eosin to one ounce of alcohol) for an hour, or the sections may remain in this solution for any length of time, as the eosin only acts upon the tissue elements to a certain extent, and no further.

(v.) Wash quickly in rectified spirit. If the sections are allowed to remain in the spirit the eosin staining will be removed, hence it is necessary merely to *rinse* them in spirit and transfer them quickly to oil of cloves previous to mounting them in canada balsam or dammar solution.

The successful mounting of stained sections in canada balsam or dammar solution very largely depends upon the course of previous treatment. To ensure good results, the following details should be attended to:—

(a). The sections must be deprived of any water they may contain by soaking them in rectified spirit or alcohol.

(b). They must be *cleared*. For this purpose turpentine and the essential oils are used, especially cajeput oil, and the oil of cloves. The sections, on removal from the spirit or alcohol, are to be *floated on to the surface* of a watch glass full of oil of cloves; the oil in a few minutes will permeate the tissue, which may be removed and mounted in canada balsam or dammar solution as soon as it sinks to the bottom of the oil.

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* Rectified spirit of sp. gr. 0·838 should be used here; where, however, it cannot be easily procured ordinary methylated spirit may be substituted.

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HUMAN BONE.

T. S. Compact Tissue of Shaft of a Long Bone.

× 50.

Etymology.—Bōne, n. [A-S. *bân*, O.S. and Sw. *bên*, Dan. and D. *been*, Icel. and Ger. *bein*, Goth. *bain*, bone and leg; Lat. *os*, *ossis*, Gr. ὀστέον, a bone.] *(Anatomy)*, One of the connective tissues formed from the metamorphosed descendants of cartilage or connective tissue cells. It exhibits two typical structural phases:—1°. A number of cells with stellate ramifying processes, which anastomose freely with one another, are surrounded by a lamellar calcified matrix, and occur in the [illegible] vertebrated animals. 2°. An apparently homo- [illegible] approximately parallel wavy cell [illegible] calcified membrane, the cells from [illegible] enter into the composition of the [illegible] of it. This kind of osseous tissue [illegible]s, and the dental organs of all the

CORRECTION

On page 24, end of 45th line, for "was" read "as"

[illegible]nd elastic structure, and eminently suited as a skeletal [illegible] [illegible]imbs and trunk, and for shielding delicate organs, such as the brain and spinal cord. In these situations it occurs in all the vertebrated animals. Its hardness is due to a calcareous deposit, which is intimately associated with its fibrous tissue; to this latter it owes its toughness and elasticity. The calcareous material may be removed by maceration in dilute acids, which leave the form of the bone intact, and enable us to make out its fibrous character, for it then has the consistence of cartilage (in consequence of which it has been inappropriately termed *bonecartilage* or *ossein*), and can be sliced or teased out like an ordinary soft tissue. The fibrous element of the bone may be removed by ignition, when, although the shape of the bone remains unaltered, the calcareous matter alone remains as a brittle and friable mass.

Description.

Bones are classified by anatomists in accordance with their external forms as *long* or *cylindrical*, *short* or *irregular*, and *flat* or *tabular*. Their texture permits of a twofold division into *dense* or *compact*, and *spongy* or *cancellated* tissues; but a minute examination with a lens shows that there is no essential difference between these two kinds of bone, and that it is rather one of degree than of kind, for they gradually merge into one another. If a vertical section be made through a long bone such as the humerus or femur, it will be seen that it contains an irregular hollow

central space termed the *medullary canal* surrounded by cancellous, which towards the periphery passes into compact tissue. It may also be observed that the dense bone forms a thicker layer at the middle of the shaft, and gradually thins away towards the extremities, where it entirely ceases to exist, and gives place to caps of epiphysal cartilage. The cancellous tissue, on the other hand, forms the entire articular ends. In all these arrangements we see a combination for the providing of the greatest possible strength with a minimum of matter; the compact tissue is thickest in that part of the shaft (the middle) which is subjected to the greatest leverage strain, and the tubular character of the bone endows it with lightness and a capability of resisting external forces more effectually than a solid arrangement of the same amount of osseous tissue. The short or irregular bones are formed of cancellous, with only a superficial coat of compact tissue (*e.g.* in the carpal, tarsal, and other bones). Flat or tabular bones, such as those of the skull, consist of an internal spongy substance or *diplöe*, covered externally by a thin lamina of very hard compact bone, termed the *vitreous layers* by GLASTAFELN.

In 1838 SCHWANN first enunciated the great morphological law that animal tissues, however diverse in structure or function, are, like those of plants (as first shown by SCHLEIDEN*), built up of cells. He says** "*that there is one universal principle for their development, and that principle is the formation of cells.*" Now, it is very difficult for us to imagine, at first, that the transverse section of dense bone before us is in reality an aggregate of cells; yet a study of the development of bone, and a right appreciation of the signification of the term cell, as defined by RUTHERFORD†, compels us to accept Schwann's statement here. The section under consideration exhibits a number of large apertures, which are the transverse sections of a series of channels termed *haversian* canals (after their discoverer CLOPTON HAVERS); around these are concentrically arranged layers of tissue termed *lamellæ*, between which may be seen somewhat compressed ellipsoidal spaces, the *lacunæ*, from which minute canals, the *canaliculi* radiate. In some cases spaces larger than the haversian canals obtain, and are either devoid of, or possess, but few lamellæ around them; they occur most frequently in young and rapidly growing bone, but TOMES and DE MORGAN‡ have shown that they may be found at all periods of life. These *haversian spaces* usually become haversian canals by the deposition within them of bony lamellæ; the fixing of the bone corpuscles in concentric series forming the lacunæ. The growth takes place in the haversian spaces from without inwards, and the *haversian system* thus formed may be regular or irregular in shape according to two variables, viz., the original form of the haversian space, and the growth inwards along the lines of least resistance. Each haversian system thus constituted is composed of a bony cylinder made up of layers of lamellæ,

*In Müller's Archiv, 1838, p. 137.

**Sydenham Society's translation of Schwann's *Mikroskopische Untersuchungen*, London, 1847, p. 165.

†A Text-Book of Physiology, Edinburgh, 1880, pp. 27-30.

‡Philosophical Transactions, London, 1853, part i, p. 109, etc.

lacunæ, and their canaliculi; and the cylinders generally lie side by side along the bone in the direction of greatest strain.

So far we have fully considered the general aspect of our section of unsoftened bone. To fully understand the structure of bone, recourse must be had to decalcifying and other methods of manipulation, and longitudinal as well as transverse sections ought to be studied.

THE MEGASCOPIC AND MICROSCOPIC CHARACTERS OF BONE.—We have already alluded to the arrangements of dense and spongy tissue in bones. With the aid of a simple lens these can be made out more distinctly, and if a longitudinal section of a long bone be examined, its haversian canals may be seen to consist of a series of longitudinal and somewhat parallel passages which anastomose obliquely with one another, and have an average diameter of from 112·8μ to 14·9μ with extremes on both sides*, they open both on the surface of the bone and internally by wide funnel shaped apertures. If a softened section of bone be examined, the haversian canals and spaces are seen to contain bloodvessels, connective tissue, &c., which enter the bone obliquely from the *periosteum*—its vascular investing membrane. The medullary canal and cancelli are chiefly filled with marrow, bloodvessels, and connective tissue.

THE LACUNÆ.—A thin section of unsoftened bone examined with powers of from 50 to 800 diameters, shows the lacunæ to be ellipsoidal compressed cell-spaces with a length of 18·1μ—51·4μ, a breadth of 6·8μ—13·5μ and a depth of 4·5μ—9μ, (FREY, *loc: cit:*). A section of softened bone magnified about 400 diameters exhibits the *bone corpuscles* within the lacunæ as nucleated cells without processes (BEALE).

THE CANALICULI are minute, branched, tortuous, anastomosing canals which connect neighbouring lacunæ. They can be made out in sections of dry unsoftened bone with a power of about 50 diameters; but it requires a magnifying power of from 800—1,200 diameters to disclose all their characteristics. They penetrate the calcified matrix of the bone, radiating in all directions from the lacunæ; their outer walls appear to consist of a calcified membrane which differs from the matrix of the bone and is a continuation of a similar structure which lines the lacunæ. VIRCHOW is of opinion that the canaliculi serve as lymph channels for the irrigation and nutrition of the bone corpuscles and osseous tissue generally. The canaliculi of each haversian system anastomose freely with one another and sometimes with those of neighbouring systems, but they more generally bend back into their own system, the "*recurrent canaliculi*" of RANVIER.

THE MATRIX of bone, like that of cartilage, appears to have a dual character. It consists of:—1° A delicate, evidently calcified, membrane lining the lacunæ and canaliculi (DONDERS and VIRCHOW†). 2° A calcified fibrous tissue arranged in the form of concentric lamellæ. The lamellæ can be made out most clearly in decalcified bone, but they may

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*The Histology and Histochemistry of Man by HEINRICH FREY, translated by ARTHUR E. J. BARKER, London, 1874, p. 240.

The Greek letter μ is here used in its ordinary technical sense to signify *micromillimetre*. $1\mu = 0{\cdot}0000397$ inch.

† Verhandlungen der physikal-medicin. Gesellschaft zu Würzburg, 1850, p. 193.

also be observed in sections of unsoftened bone. They were first discovered by SHARPEY,* who describes them as consisting of a fine network of transparent fibres, which coalesce at their intersections. The lamellæ may be readily stripped off from the surface of a long bone, which has been decalcified. Magnified about 400 diameters, the fine reticulum can be made out, and every here and there are closely set minute pores, which represent canaliculi, torn across; occasionally, larger apertures occur, these are the sockets out of which certain fibres, the *perforating fibres of* SHARPEY† have been forced. The lamellæ have between them an interstitial cementing substance which appears to be the seat of the calcareous deposition of the osseous tissue. A transverse section of dry unsoftened bone highly magnified, has a granular appearance, which is due to the alternating layers of lamellæ of unequal density, and interstitial cementing substance, as much as to the deposit of calcareous particles which also probably impregnate the lamellæ. The lacunæ are disposed in concentric series between the lamellæ, of which there are generally from two to five between neighbouring lacunes.

Between the haversian systems in our section, may be seen *intermediate lamellæ*. These appear to be portions of the lamellæ of something larger than haversian lamellæ, although occasionally they are formed from haversian systems. They usually result as the products of absorption and encroachment by the haversian canals, on the *peripheric lamellæ* of the bone, *i.e.*, lamellæ which were originally formed immediately under and by the periosteum. Other lamellæ also occur in bone: in the medullary region these are essentially similar to those already described, but from their position are termed *cancellous lamellæ*. The intermediate and peripheric lamellæ of bone are then original growths. The haversian and cancellous lamellæ, on the other hand, are secondary formations which take place in haversian and medullary spaces formed by the absorption of the bone.

METHODS OF PREPARATION.

PRELIMINARY.—The fresh bone cut into pieces should be macerated in water for some months, until all traces of soft parts have been removed. To accelerate the maceration, and make sure of obtaining a thoroughly cleansed bone, the process should be conducted in a room at the ordinary summer temperature, and the water should be changed about once a week. The bone must not be permitted to dry before maceration, or else it will be indelibly stained with grease from the marrow. Where it is desirable, however, to cut sections of bones which have not been well macerated, they may be cleansed tolerably well by soaking slices in ether for about twenty-four hours, and then washing them thoroughly in water. If the bone contains a large amount of cancellous tissue, it should be soaked in a strong solution of gum until it is quite saturated with it, then hardened for a day in methylated spirit, and set aside to dry. Thin slices (from 1-8th to 1-10th inch) may then be cut off by means of a fine ~~was~~ saw in any desired direction, and it will be found in the case of cancellated tissue with hardened gum, that the cancelli are supported *in situ* by the gum.

* Quain's Elements of Anatomy, London, 8th Edition, 1876, p. 86.
† Quain's Elements of Anatomy, London, 8th Edition, 1876, pp. 87-89.

1ST PROCESS.—The slices thus obtained must be ground perfectly flat and smooth on one side. This can be best effected on a fine grained thoroughly flat Water-of-Ayr stone or Turkey stone. If slices with cancellous tissue supported by gum are to be ground, methylated spirit should be used with the stone; in other cases, water suffices. It will be learned that the slice of bone can have its surface rendered perfectly flat and even polished on the stones mentioned.

2ND PROCESS.—The flat smooth surface of the slice must be fixed on to a stout slip of glass, as follows:—Place a few drops of old canada balsam on a slip of glass, heat it over a spirit or bunsen flame until the balsam is rendered sufficiently hard yet tough enough to fasten the section to the glass on cooling; this may be tested by removing a small portion of the balsam and allowing it to cool between the thumb and finger; it may be considered sufficiently baked if the balsam becomes just hard on cooling. Precautions should be taken not to overbake the balsam, as it then becomes friable, and, therefore, useless as a cement. A little practice will enable anybody to judge when the balsam should be removed from over the flame, by merely noting its appearance, without going to the trouble of testing it every time. The polished surface of the slice must be applied to the hardened balsam *as it is getting cool*, and the superfluous balsam between it and the glass slip, pressed out to the exclusion of bubbles of air. The balsam thus squeezed out ought to be carefully removed and the slide laid aside, under a clip, if necessary, until it becomes perfectly cold. If these details are not strictly adhered to, and the slice is placed on the balsam whilst still hot, it will inevitably result in a destruction of the slice by warping; and if the superfluous balsam is not scraped away from the slide before it hardens, its removal after hardening may detach the slice from the glass slip; it is necessary to remove it because its presence retards the subsequent process of grinding, and harbours particles of grit and dirt, which may prove fatal to the section when it is being ground very thin. The process just described will effectually fasten the slice of bone to the glass slip.

3RD PROCESS.—The other side of the slice may now be ground down on the stone until it is reduced to the requisite degree of thinness. To ascertain this it should be frequently examined under the microscope.

4TH PROCESS.—The application of a gentle heat will be sufficient to detach the section, which should be thoroughly well washed in a watch glass full of benzol or soaked in ether to remove any traces of grease which may exist.

Bone sections thus prepared may be mounted dry, *i.e.*, in air; they may also be mounted in glycerine jelly, canada balsam, or dammar solution. Only thoroughly well macerated bones admit of dry mounting without having their beauty impaired. If they are slightly discoloured they should be mounted in glycerine jelly. Canada balsam and dammar solution are seldom used because they obliterate structure by rendering the bone sections too transparent.

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The literature connected with the subject of bone has become so extensive, that a list of the books and papers written would completely

overwhelm these pages; nor is it our intention to compile such a catalogue. We merely satisfy ourselves by appending a list of such works as may prove useful to the student as a guide to further research, especially with regard to the vascular and nervous supply of bone, its chemistry, and developmental history.

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ANSWERS TO CORRESPONDENTS.

All communications should be addressed to the Editor, MR. ARTHUR C. COLE, St. Domingo House, Oxford Gardens, Notting Hill, London, W.

All notices, letters, and advertisements should reach the Editor not later than Tuesday morning in each week, and should be written only on one side of each sheet of paper. Attention to these details will save delay.

The Editor acknowledges the receipt of one or two complaints that the journal was delivered in a crushed condition, having been doubled up so as to permit of being pushed into letter boxes. He would be glad if subscribers would instruct their *postmen to deliver their parcels at the door, and not put them into the letter box.* This is in conformity with existing post office rules, and any postman infringing such rules is liable to punishment.

J.D.—Dr. Marsh on section cutting, published by Churchill, price 2/6, is a handy little book for those who wish to begin to cut their own sections.

"STUDIES IN MICROSCOPICAL SCIENCE."

"We have before us at this moment an interesting novel venture in microscopical science and literature. Mr. Arthur Cole, a gentleman with a well-acquired reputation for his exquisite microscopical preparations, has favoured us with the first number of "Studies in Microscopical Science," (*a*) and which he intends, he tells us, to *issue weekly*, for the use of students, teachers, the medical profession, and others interested in the progress of microscopical and the allied sciences. The attempt here made to combine a practical and technical knowledge of histology is in every way commendable, and these "studies," if carried out in the spirit in which they are begun, will no doubt prove of considerable value, not only to the student, but to the teacher, as a means of saving time. In addition to the letter-press description, which is full enough, without too much elaboration, we have a faithfully-executed coloured lithograph of the specimen under observation; and Mr. Cole engages to furnish regular subscribers, for comparison and study, with a microscopical preparation of the highest class and finished in the most perfect manner. In the present case the specimen is one of yellow fibro-cartilage from the pinna of the ear of the cow. It is shown magnified 333 diameters, double-stained in logwood and eosin. The descriptive part may be relied upon as in every way accurate. The differentiation of the structural elements, the shape of the cells, the matrix and other typical characters of the specimen are very fully considered. The methods of staining employed in the preparation of kindred sections as a means of study are given with a fulness that will give delight to the practical microscopist. An extended bibliography is added, and will afford the student a ready and very useful means of reference to those authors who have by their labours enriched and enhanced the bearing on literature of the subject."—*Med: Press and Circular.*

"Under the title 'Studies in Microscopical Science,' Messrs. Baillière, Tindall & Cox have published the first of a series of papers, which form an entirely new departure in literary work. The 'Studies' are to be issued weekly, and will each consist of descriptive letterpress of some one microscopical object, of which an accurate and careful illustration will be presented, and at the same time also a prepared section of the object, cut and mounted by Mr. Arthur E. Cole, F.R.M.S., whose histological and other slides have obtained a world-wide celebrity. The first number of the work comprises an account of yellow fibro-cartilage, and for excellence and fidelity of execution the accompanying lithographic drawing is superior even to those contained in the best atlases. The section issued with the paper is, moreover, a very beautiful object, stained with hæmatoxylin and eosin, and promises well for the utility and popularity of the series."—*Med: Press and Circular.*

HUMAN SKIN.

V. S., Sole of Foot.

Stained Carmine and Sulph-indigotate of Soda.
× 65.

Etymology.—Skin, *n.* [A-S. *scinn*, Icel. and Sw. *skinn*, Dan. *skind*, O.L. Ger. *schin*, *schinn*, Lat. *cutis*, Gr. δέρμα, gen. δέρματος, skin, from δέρειν, to skin flay]. *(Anatomy* and *Physiology).* In many of the lowest forms of animal life *(Protista)* the whole of the organism is so primitive in structure that the highest available power of the microscope utterly fails to demonstrate an external investing layer worthy of the name of integument; in some of them, however, a faint separation into *ecto*—and *endoplasm* occurs. As we ascend in the scale of life, and observe some of the simpler *Metazoa*, we find a distinct outer layer of cells *(ectoderm)* fulfilling the functions of an integument, provided with accessory organs for special purposes *(Hydrozoa*, etc.*)*, secreting a hard protective membrane *(Arthropoda)*, a calcareous outer shell *(Mollusca)*, or a soft test *(Ascidia).* In the hard test of the *Echinodermata* the integument owes its origin to the incorporation of the *mesoderm* with the ectoderm in the formation of an intricate areolar calcified tissue. In the higher forms of animal life *(Vertebrata)* the skin admits of a rough division into two parts, the *cuticle* or *epidermis*, and the *cutis vera*, *corium*, or *dermis.* The embryonic *blastoderm* which results from the cleavage of the vitelline substance of the fertilised ovum very early subdivides into two layers; the *mucous stratum* or *hypoblast*, and the *serous stratum* or *epiblast.* It is from a part of the epiblast that the epidermis of the skin is developed. A third germinal layer, called the *intermediate stratum* or *mesoblast*, makes its appearance between the other two, and gives rise to the *corium* of the skin. Both of these elements may become the seat of complex chemical and structural changes destined to perform the functions of a protective, tactile, excretory, and absorbing organ.

In the lowest class of undoubted *Vertebrata (Pisces)* the epidermis persists as a soft delicate membrane, whilst the corium develops in all Fishes, except the two lowest orders *(Pharyngobranchii* and *Marsipobranchii)* numerous lamellar calcified plates *(scales)*, which in some take on the characters of cartilage and true bone *(Accipenser*, *Scapirhynchus)*, whilst in others they exhibit the textures of true teeth arranged in linear superposed series (the *placoid scales* of the Sharks and Rays, and the fossil *ichthyodorulites).* In all Fishes the deeper layers of the skin of the *fin-rays* becomes peculiarly and characteristically modified.

The integument of the *Amphibia* remains soft throughout, and develops in many of them superficial glands and contractile pigment cells of great

physiological interest.* There are, however, exceptional cases in which the dermis gives rise to minute lamellar scales *(Cœcilia)*, and to bony plates and scutes *(Ceratophrys, Ephippifer*, and some of the extinct *Labyrinthodonta)*.

In the *Reptilia* we find that both parts of the skin become very variously modified; the epidermal layers in the soft Tortoises *(Trionyx)* are unaltered; in the remaining genera they form the so-called "Tortoise-shell," whilst the deeper portion of the integument gives rise to a complicated bony exoskeleton which, however, does not correspond in position with the epidermal plates. Amongst the Lizards *(Lacertilia)* the *Chamæleonida* and *Amphisbænoida* possess a soft skin which in the Chamæleons takes on a tuberculated character and contains peculiar pigment granules deposited in special receptacles *(chromatophores)* which are developed in the corium. The epidermis in all other *Lacertilia* becomes hard and horny and produces plates, overlapping scales, spines, and tubercules. In some *(Cyclodus, Scincus)* the dermal layer becomes the seat of intramembranous ossifications which develop into scutes lying under the epidermic scales and simulating their shapes. Other modifications of the skin are to be found in the femoral and cloacal-glands which frequently obtain in Lizards. The Snakes *(Ophidia)* exhibit an overlapping, scaly, and chitinous epidermis; in *Acrochordus* the scales are tuberculoid and do not overlap, and in *Crotalus* the caudal extremity is terminated by several horny loosely connected rings which constitute their so-called "rattle." The corium of all *Ophidia* remains soft and unchanged. The Crocodiles *(Crocodilia)* present a very highly modified integument; the epidermis forms numerous hard horny scales which cover bony scutes of corresponding shapes which are developed in the dermis. They also possess peculiar integumentary glands situated under the lower jaw, from which a musky secretion is emitted. In those Reptiles which possess distinctly articulated and fully formed limbs, the terminal phalanges are covered by epidermic plates in the form of *nails*, and similar horny plates ensheath the beak where that structure occurs.

The epidermal layer of the skin in Birds *(Aves)* produces numerous horny arrangements which are adapted to the wants of the different parts of their bodies; thus the trunk and limbs are clothed with *feathers*, the legs with scales and nails, and the beak with a sheathing plate. No important structural change takes place in the dermis, unless we regard the spurs on the legs and wings of some species as of this nature. The greater part of the skin is free from glandular organs; in most birds, however, a large sebaceous gland with one or two external apertures is situated in the integument over the coccygeal region, and is known as the *uropygial gland*. The skin about the head and neck in some Birds (*e.g.*, the Pigeon, Fowl, and others) becomes curiously developed into large vascular appendages sometimes composed of erectile tissue, and forming *wattles, combs, &c.*

The highest class of the *Vertebrata (Mammalia)* is constituted by fourteen groups of animals whose tegumentary organs are very diversified in their modifications. With the single exception of

* See WITTICH in *Müller's Archiv*, Berlin, 1854, and LISTER, *Phil. Trans.*, London, 1858.

feathers every chief variety of epidermis already noted may be met with. Thus we find spines *(Echidna)*, scales *(Manis)*, and plates *(Armadillo)*, whilst most of the other mammals develop *hairs*. Some *Cetacea* are unique in the possession of a completely soft skin, which is provided with only a few hairs in the fœtal state. The horns and hoofs of Ruminants, etc., furnish us with examples of a closely set chitinous sheathing epidermis, which in others, as in Man, is exhibited in the form of nails. The corium remains soft in all *Mammalia* with the exception of the loricated *Edentata (e.g., Armadillo, Chlamydophorus)* in which it produces a series of bony scutes. The integument of Mammals is largely provided with glands of many kinds; such are the *sebaceous follicles* which are situated at the roots of the hairs, the *sudoriferous glands*, *musk glands*, and *mammæ*.

Description.

In our consideration of the tegumentary organs, we have selected an example in the skin of the Human subject taken from the plantar region of the foot as illustrative of a special inquiry. The section has been cut in a vertical direction at right angles to the surface of the sole, and has been stained with carmine and sulph-indigotate of soda. Our drawing was taken from a specimen in which each colour has confined itself to a distinctly marked area of the tissue; the blue of the sulph-indigotate of soda has stained the horny layers of the epidermis exclusively, whilst the red of the carmine has been attracted by the rest of the section. In some cases, however, the blue shows a tendency to diffuse itself more extensively, and tinges other parts of the preparation. With a magnifying power of 65 diameters the different parts of the skin may be clearly recognised. In the part of the epidermis which has been stained blue we can make out two distinct portions; the *stratum corneum (a)* composed of numerous horny cells forming a comparatively thick layer of stratified squamous epithelium, and immediately below this a narrow somewhat homogeneous band, the *stratum lucidum* of Schrön *(b)*. Beneath this there is a narrow layer of spindle-shaped granular looking cells *(c)* called the *granular layer*, or *layer of Langerhans*, and the remainder of the epidermis which lies between this and the corium forms the *rete Malpighii* or *rete mucosum (d)*. These two last named layers are coloured red. The *papillary layer (e)* of the corium may be seen closely apposed to the epidermis above it, and overlies the *subcutaneous connective tissue (f)* which contains the coiled tubes of the *sweat-glands (g)*. Clusters of fat cells *(h)* forming a *panniculus adiposus* may be seen in the neighbourhood of the sweat-glands, and every here and there the transverse section of an artery *(i)* may be detected. The external orifice *(k)* of the sweat-gland is shown leading into a spirally twisted tube which after passing through the epidermis becomes somewhat straightened until it joins the gland below. Occasionally a *Pacinian body* or a *Meissner's corpuscle* may be seen, but we have not figured these in our illustration.

According to C. Krause, the epidermis of the human subject has an average depth in most parts of 0·0751—0·1735mm.; it attains the greatest thickness in the palm of the hand and the sole of the foot, is stronger in males than in females, and in children under seven years of

age is scarcely one-half as deep as in the adult. The cuticle consists principally of two layers of stratified squamous epithelium, the *horny layer* and the *soft layer*; the horny layer varies in thickness from 0·0347—2·26mm., whilst the soft layer, which is more constant in its depth, ranges from 0·0347—0·1128mm. (Frey).

The epithelial cells proliferate in the lower part of the soft layer, where the nuclei of the cells may be seen undergoing division, and are forced upwards into the horny layer, to give place to the multiplication which goes on below. In the course of this upward passage, they are changed in character; they increase in size, their protoplasmic contents dwindle gradually away, whilst their cell walls become thicker and cornified; their nuclei may vanish altogether, and they are finally removed from the surface of the skin, as scaly plates, by friction.

Although it thus appears, from developmental considerations, that no primary distinction can be drawn between the different parts of the epidermis, the morphology of its cells, and the functions which they perform, have led anatomists to distinguish them into four layers:—(i.) An outer superficial layer, the *stratum corneum*, composed of a stratified zone; towards the superficial periphery of the skin its cells become quite flattened, and most of them loose their nuclei. (ii.) The *stratum lucidum* of Schrön, consisting of a narrow, apparently homogeneous, obscurely striated band of horny cells, in which staff-shaped nuclei may be detected. (iii.) The *granular layer* of Langerhans, which constitutes the uppermost layer of the soft part of the epidermis, and is made up of somewhat flattened, spindle-shaped cells, with distinct large nuclei; the protoplasmic contents of each cell exhibit numerous granular masses, which are largest near the nucleus. (iv.) The *rete Malpighii*, or *rete mucosum*, constituted by a layer of columnar cells, with large oval nuclei, closely apposed to the papillary layer of the skin, and surmounted by polyhedral cells of a similar nature. The cells in the lowest layers of the rete mucosum may be seen undergoing division; this is indicated by the division of their nuclei, but it is extremely difficult to trace the division of the cells themselves, which probably takes place by the formation of lines of vacuoles (Rutherford). These cells are also peculiar in being connected with one another by fine filaments, as pointed out by Bizzozero and Heitzmann. Max Schultze* maintained that the processes of these so-called "prickle" cells are interlocked with one another, and thus give rise to the denticulate appearance of the edges of the cells; but it has been shown by Martyn† that these prickles are continuous at their apices. Klein** is of opinion that the prickles are fibrils uniting the substance of contiguous cells, which he describes as a very dense network. The most plausible explanation of the true significance of these cells, however, is that accepted by Rutherford‡ who states that Ranvier's method of hardening in osmic acid§ "reveals the contour of the cell, marked by a line of rounded spaces between which the so-called 'prickles' stretch as bridges between the

* *Virchow's Archiv*, Bd. 30, s. 260.
† *Monthly Micros. Journ.*, London, xvi, p. 59.
** *Atlas of Histology*, London, 1880, p. 16.
‡ *A Text Book of Physiology*, Edinburgh, 1880, pp. 66-67.
§ *Traité Technique d'Histologie*, Paris, 1875, p. 261.

cells;" he goes on to say that "the prickles seen on detached cells apparently result from the rupture of these bridges by mechanical methods employed for isolating the cells," and that "the spaces between the bridges are probably channels through which the lymph permeates from the subjacent capillaries to nourish the growing cells of the *rete mucosum.*" The lowest cells of the Malpighian layer of the epidermis are closely attached to the corium underneath, and their downward processes dip into the fibrous tissue of the dermis; in the neighbourhood of the sweat glands these cells often dip down around the tubules to a considerable extent in the form of an investing layer of epithelium.

The cells of the epidermis vary in size from 0·0425—0·0750 mm., those of the deepest layers of the rete mucosum, and to a less extent its other strata, contain pigment granules which usually aggregate around their nuclei.

The *true skin, cutis vera, derma,* or *corium* consists of a highly vascular and nervous structure of connective tissue, the uppermost portion of which is raised up into numerous prominences or *papillæ;* its lower layers gradually pass into a loose *subcutaneous areolar tissue* which contains clusters of fat cells (hence the name *panniculus adiposus* which has been applied to it) and lodges the convoluted tubules of the sweat glands, &c. The tissue of the corium is composed chiefly of a network of white fibrous tissue largely intermixed with elastic fibres, and a complicated system of connective tissue corpuscles with reticularly anastomosing processes, together with numerous lymphoid independent cells. In the papillary and highest layers, the fibres are very fine, closely packed, and appear to form a homogeneous stratum; the limitary layer thus formed is the *immediate membrane of* Henle, or the *basement membrane* of Todd and Bowman. Lower down the fibres are coarser and more loosely interlaced, and pass by a gradual transition into the subcutaneous areolar tissue.

Unstriped muscular fibres occur in the skin in the vicinity of hairs; they rise from the superficial layer of the corium and pass obliquely downwards to be inserted into the outer portion of the hair follicle on that side to which the hair slopes. Similar circularly disposed fibres have also been described as existing immediately around the follicles, and in certain situations (the nipples and their areolæ, the penis, the *tunica dartos* of the scrotum, and the perineum) obtain in the subcutaneous tissue. J. Neumann has described bands of non-striped muscular fibres which pass from the upper part of the cutis into the panniculus adiposus, and branch freely in all directions; and numerous fibres have been traced below the sweat glands and tactile corpuscles, etc. Striated muscular fibres do not occur in the skin; in certain parts they merely attach it to subjacent structures, *e.g.*, the *orbicularis oris,* the cutaneous muscles of the face and neck, the *panniculus carnosus,* etc.

The papillæ of the corium may be either simple, or compound, *i.e.*, cleft into two or more parts; they vary very considerably in size, shape, and numbers in different parts of the body. The largest papillæ are to be found on the volar side of the hand, the plantar region of the foot,

and the nipple; they measure from 0·1505—0·23mm. in length, and may be conical tongue shaped, or altogether irregular; in the skin of the face they may be reduced to mere elevations which range from 0·0451—0·0377 mm. and less (FREY). In the skin of the palm and that of the sole they are arranged in linear series, and give rise to the well-known ridges and furrows of those parts; in the ridges they are usually placed in a double row, and the furrows are caused by the dipping down of the epithelium between these rows; at short intervals the ridges are marked by a number of small depressions, which are the orifices of the sudatory glands. In other parts of the body the papillæ are indefinitely arranged and in all parts, more notably the back of the hand, produce numerous intersecting furrows and isolated ridges.

The corium is very richly supplied with bloodvessels which are derived from the vessels of the subcutaneous tissue, in which they form meshes around the clusters of fat cells, hair follicles, and sweat glands; they pass into the corium, where they form a very intricate system of capillaries, which spread out in a horizontal direction, and supply most of the papillæ with capillary loops. The researches of TEICHMANN and NEUMANN have revealed a very complicated lymphatic system in the skin; it consists of a dense meshwork of large vessels containing valves, in the subcutaneous tissue, passing into a finer plexus of valveless vessels in the corium, which may give off diverticula, and enter the papillæ either as simple tubes or as loops. The nutrition of the rete mucosum by means of the lacunar system of the so-called "prickle" cells has already been alluded to.

The nervous system of the skin finds expression in numerous plexuses, from which their branches divide and subdivide as they pass towards the papillary layer of the corium, to terminate finally in either bulbous extremities or in very delicate fibrils in the *rete mucosum*. They supply the glands and hairs of the skin, and very often end in peculiar terminal organs, which have been called *Pacinian bodies*, *tactile corpuscles*, and *end bulbs*. The Pacinian bodies are to be met with in the subcutaneous tissue, the tactile corpuscles occur in special vascular or non-vascular portions of vascular papillæ in the palm, sole, and many other parts of the body, whilst the end bulbs are to be found on some of the papillæ of the red portion of the lips, the *glans penis* and the *glans clitoridis*. As may be expected, the nervous supply is always found to be directly proportional to the sensibility of the part, and thus varies to a considerable extent in different regions.

METHODS OF PREPARATION.

LISTER'S METHOD FOR THE OBSERVATION OF THE "PRICKLE" CELLS.—Place the foot in hot water for about half an hour, scrape off the epidermis, and macerate it for some time in a $\frac{1}{6}$ per cent solution of potassium bichromate. On teasing the tissue thus prepared the prickle cells will be rendered apparent under a magnifying power of from 700-1000 diameters. Thin sections of skin made from pieces which have been hardened in a $\frac{1}{6}$ per cent. solution of potassium bichromate, with a few drops of carbolic acid in it, may also be teased out for the observation of

the prickle cells. The epidermic horny cells may be advantageously studied after soaking in a strong solution of potassium hydrate.

RANVIER'S METHOD.*—Inject a ¼ per cent. solution of osmic acid into the rete mucosum by means of a hypodermic syringe, introduced obliquely into the skin; cut out the piece thus prepared, and harden it for a day or two in rectified spirit. Vertical sections may now be made and preserved in glycerine. It will be found on examination with a high power (× 700-1000) that the osmic acid has stained the protoplasm of the prickle cells a neutral tint, and reveals the lymph spaces which we have noted in our description. Osmic acid was introduced into histology as a hardening re-agent by MAX SCHULTZE; it may be obtained in the form of small glassy-looking particles in sealed tubes, but it is best procured as a 1 per cent. solution in distilled water. It should be kept in a well-stoppered bottle, and carefully protected from the light; its vapour is extremely irritating, especially to the nostrils, and as it is very poisonous it should be cautiously used. It is specially useful in hardening delicate tissues, such as embryos, etc., as it does not cause any great shrinkage of the tissue elements, and slightly darkens them, whilst it blackens particles of a fatty nature. To harden tissues they should be placed in it according to their requirements, ranging from a few minutes to forty-eight hours, then washed in distilled water, cut into sections, and mounted in a saturated solution of potassium acetate, or in glycerine.

STIRLING'S METHOD OF DIGESTION.†—The value of this method in the study of the skin depends upon the fact that digestion acts more rapidly upon some tissues than on others, and thus by partially changing or entirely removing certain structures, reveals the presence of others or renders them more conspicuous. Its partial action upon skin has the effect of causing the white fibrous tissue to swell up and become transparent, and thus permits of the study of the other elements. We cannot do better here than give Stirling's method in his own words:—"Make an *artificial gastric juice* by mixing 1 cc. of pure hydrochloric acid with 500 cc. of water, and add one gramme of pepsine, or a few drops of a glycerine extract of the gastric mucous membrane. It is well to keep the mixture at 38° c. for two or three hours before using it. The piece of skin to be digested is stretched over a small glass ring and firmly tied to it. It is then placed in some (200 cc.) of the digesting fluid, which is kept at a temperature of 38° C. in an ordinary water bath for a period varying from three to eight hours,—the time depending upon the age and size of the piece of skin. After partial digestion the skin is placed in water for twelve hours when it swells up and becomes extremely transparent. It may be kept most advantageously in a ten per cent. solution of common salt, or it may be hardened in one of the ordinary hardening fluids, and afterwards stained with logwood or carmine."

This method may be used with other tissues also, it has been employed successfully by BIRCH in the study of bone, and by KÜHNE in his researches on the structure of nerves.

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* See *Traité Technique d'Histologie*, par LOUIS RANVIER, Paris, 1875, p. 261.

† *A Text Book of Practical Histology*, by W. STIRLING, London, 1881, pp. xxxiv-v. 92-3.

STAINING WITH CARMINE AND SULPH-INDIGOTATE OF SODA.

PRELIMINARY.—*Hardening the Skin.*—Small pieces of the skin cut from various parts of the body should be placed in a solution of chromic acid and spirit for about 18 hours, the fluid should then be renewed and the tissue allowed to remain in it for from 10 to 30 days; they should then be removed to rectified spirit for a few days when they will be found sufficiently hardened to be cut in the microtome in a piece of carrot, imbedded in paraffin, or frozen in gum solution.

To make the *Chromic Acid and Spirit Solution** :—"Dissolve 1 gramme chromic acid in 20 cc. water, and *slowly add it* to 180 cc. rectified spirit."

1ST PROCESS—*Staining in Carmine.*—The sections are to be placed in an ammoniacal solution of carmine for from 5 to 10 minutes, or until they are thoroughly stained and then washed in rectified or methylated spirit.

Take of Carmine.....drm. i
Ammonia (fort.).....drm. ii.

(A). Dissolve the carmine in the ammonia with the aid of a gentle heat and filter. (B). Make a saturated solution of borax in distilled water and filter it. Add A to B, filter.

2ND PROCESS.—Remove the sections from the spirit into the following solution for about 10 minutes :—To five parts methylated spirit add one part of pure hydrochloric acid. Wash in strong rectified or methylated spirit, and allow the sections to remain in this for an hour or two, so that all trace of the acid may be removed.

3RD PROCESS.—*Staining in Sulph-indigotate of Soda.*—Transfer the sections into a large quantity (two or three ounces) of the following, for from six to eight hours :—Add two or three drops of a saturated solution of sulph-indigotate of soda to one ounce of methylated spirit. This solution should be made as required, from time to time.

4TH PROCESS.—*Mounting the Sections.*—The directions given in this journal at pp. 6, 15, and 16, may be followed here, and the sections mounted in Canada balsam or dammar solution.

Sections of skin may be stained in logwood and picrocarmine* ; thus treated the horny layers of the epidermis are rendered yellow, the rete mucosum and sweat glands a logwood-tint, and the connective tissue, &c., red. They may also be stained with logwood and iodine-green, but we cannot recommend this method, as the green dye is very fugitive. For the time being, however, they make very beautiful preparations, the hard layers of the Epidermis are stained yellow, the rete mucosum, sweat glands, and nuclei of the fat cells and connective tissue corpuscles, green, and the fibres of the connective tissue red. The method of staining with gold chloride and osmic acid‡ has been employed for the purpose of demonstrating the tactile corpuscles and nerves of the skin.

* See RUTHERFORD, *Outlines of Practical Histology*, London, 2nd edition, 1876, p. 3.

‡ See this Journal, p. 6.

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PIKRITE.

Inchcolm, Firth of Forth, Scotland.

× 25.

Etymology.—PIKRITE, *n.* Evidently so called because its green constituents, which sometimes take on a fibrous texture, cause it to resemble *picrolite*, a bitter fibrous variety of serpentine, of a green colour. [Gr. πικρός, bitter, and λίθος, stone].

DESCRIPTION.

Amongst the numerous rocks of igneous origin there are perhaps none which puzzle the petrologist so much in his attempts at a rational classification as the small group which seem to pass by a gradual transition into *serpentine*. Comparatively few such rocks have yet been discovered, but wherever the stratigraphical details have been worked out in conjunction with their mineralogical characters, they seem to establish the igneous origin of serpentine. Thus PICOT DE LA PEYROUSE* described a rock which occurs in masses around the Etang de Llherz, amongst veins of limestone, near Vicdessos, in the Eastern Pyrenees, which DELAMÉTHERIE** named *llherzolite* after its locality. According to DESCLOIZEAUX*** it consists of olivine, an infusible brown pyroxenic mineral, allied to hypersthene, a green fusible pyroxene, and numerous granules, with occasional octahedra of picotite disseminated through the rock.

DAMOUR† subsequently worked out its mineral constitution, and states it to be composed of olivine, enstatite, diopside, and picotite, which occur in abundance in the order just quoted, the olivine forming the greatest bulk of the rock. The investigations of VON LASLAUX‡, and, more recently, those of BONNEY††, have established that this rock becomes so metamorphosed in certain parts, that it is fully entitled to rank as a serpentine, and BONNEY is of opinion that it is of intrusive igneous origin; he goes further still, and states § that the serpentine of the Lizard, in Cornwall, in which he has discovered decomposed olivine, enstatite, and picotite, is a metamorphosed intrusive llherzolite. Rocks which closely resemble llherzolite have been found in Norway, the Tyrol, the depart-

*Mem. Acad. Toulouse, iii, p. 410..
**Théorie de la Terre, 1797, T. ii, p. 281.
***Manuel de Mineralogie, I, p. 65, etc.
†Neues Jahrb. f. Min., 1863, p. 95, etc.
‡Elemente der Petrographie, Bonn, 1875.
††The Llherzolite of Ariége, Geol. Mag., Decade II, Vol. IV, 1877, p. 59, et seq.
§On the Serpentine and Associated Rocks of the Lizard District, Q.J. Geol. Soc., Vol. XXXIII, p. 923, etc.

ment of Haute Loire, Nassau, the Fichtelgebirge, and many other places, and VON LASLAÛX notices its occurrence in the form of olivine bombs in some basalts.

Nearly related to llherzolite, indeed so nearly in some instances, that F. SANDBERGER * regards it as a variety of that rock, is the *dunite* of F. VON HOCHSTETTER,† a rock which passes by gradual alteration into serpentine, and is composed of olivine and chromic-iron, with occasional crystals of diallage and enstatite, forming a crystalline aggregate of a grayish-green colour, and greasy vitreous lustre. It was first found in Dun Mountain near Nelson in New Zealand (whence its name) but has since been localised in the south of Spain and other places.

In 1866 TSCHERMAK ‡ described a rock which he called *pikrite*, and GÜMBEL under the same name characterised some of the rocks of the Fichtelgebirge. DANA,** under the head of observations on chrysolite notices a rock from Moravia, named *picryte*, which he describes as consisting half of chrysolite, along with felspar, diallage, hornblende, and magnetite, and PREYER, ZIRKEL, and VON LASLAUX all notice the rock in their petrological considerations next to llherzolite and dunite.

In its tendency to become transformed into serpentine, pikrite does resemble the two last named rocks, and it presents us with examples of undoubted volcanic rocks both in the form of coulées, and as intrusive masses. It has hitherto been found in only two localities in Scotland. It was first detected by GEIKIE in the form of a true lava-bed at Blackburn, near Bathgate, and afterwards as an intrusive mass in the Island of Inchcolm. GEIKIE*** describes the variety from Blackburn as a volcanic sheet of lava which solidified on the surface of the earth during the time when the older part of the carboniferous limestone series were accumulating in West Lothian. The rock is to be seen in Blackburn quarry only, and has been worked under the name of "lakestone" for several years, as a material used in the construction of the soles of ovens, for which purpose it is eminently adapted on account of its low thermal conductivity. The upper portion of the band is seen to be distinct from the lower part, and although no sharp line of demarcation can be drawn between them, a distinction is made by the workmen who reject the upper as too hard to be used, and utilise only the lower portion. The whole rock is traversed by irregular vertical veins of serpentine, chrysolite, and calcite, and a careful inspection shows a serpentinous basal part surmounted by a less altered upper band. GEIKIE's examination of the rock revealed the lower serpentine passing by gradual shades into a lighter more felspathic material, and from this he drew an important conclusion, viz. :—that the olivine, augite, and iron, of the original lava on account of their greater specific gravity settled in the largest proportion at the bottom of the bed, whilst it was yet sufficiently molten to permit of such segregation, and produced by their alteration the serpentine of the base,

* Neues Jahrb. f. Min., 1865, p. 449.
† Zeits. d. d. Geol. Ges., 1864, p. 341.
‡ Sitzungber. d. k. Acad. in Wien, 8 März, 1866.
** A System of Mineralogy, London. 5th ed., 1881, p. 258.
*** On the Carboniferous Volcanic Rocks of the Basin of the Firth of Forth, Trans. Roy. Soc. Edin., 1879, p. 504, et seq.

whilst the lighter felspar predominates in the upper part, and has produced the pikrite; thus proving that the remarks of SCROPE on the arrangement of the minerals in modern lava flows, can be extended in their application to those of the palæozoic age.

The upper portion (pikrite) of the Blackburn rock is stated by GEIKIE* to give the following characters:—"Finely crystalline base of a dirty, blackish green colour, and a tolerably homogeneous but dull texture, showing many ill-defined greenish white points, apparently of decayed felspar with minute facettes, some of which are pyrite; fracture, splintery; hardness, 3 to 4." "It contains among its constituents a feeble quantity of a distinct glass which occurs occasionally in large interspaces, and then shows a dusty character, resolvable with a high power into exceedingly minute dark globules. The most abundant mineral is a colourless and tolerably fresh triclinic felspar. Next in amount is a pale yellowish transparent mineral in very small prisms, which seems to be augite, but of an unusual form. Some of these prisms, not exceeding ·0005 of an inch in diameter, may be seen enclosed in the altered olivine. The latter mineral can be recognised in the form of crystals, from about ·03 to ·10 of an inch in length, completely serpentinised. They consist mainly of a pale delicate apple-green clouded and fibrous substance, which is bordered and traversed by strings of a bright grass green, sometimes of rich yellowish brown. But these olivines occur in much smaller quantity than in the lower part of the rock. Titaniferous iron or magnetite likewise appears as in that lower part, but also in less abundance. Apatite may be detected occasionally."

The pikrite of Inchcolm, which forms the subject of our illustration, occurs as an eminence at the south western part of the island, its upper surface is exposed and has evidently been laid bare by denudation; it overlies beds of hardened sandstone, limestone, and shale. The absence of any trace of vesicular and amygdaloidal structure, and the analogous condition of the volcanic rocks of the adjacent islands and neighbouring coast, indicate its probably intrusive character, and point to its contemporaneous carboniferous age. GEIKIE† in his notice of the rock says that it "is considerably fresher than that of Blackburn," and "examined under the microscope, it is seen to be by far the most beautiful rock in the basin of the Firth of Forth."

It is composed of olivine, a green alteration product, augite, a whitish fibrous zeolite, a few plates, and numerous grains of titaniferous iron, occasional scales of biotite, and a few crystals of apatite. GEIKIE** says that there is also a milky felspar, full of fissures, filled with decomposition products, but still showing traces of twin lamellation, which occupies a very subordinate place in the rock, but we have failed to detect this mineral in any of the sections which have come under our observation.

The OLIVINE, *n* [Fr. *olivine*, from Lat. *oliva*, olive, Gr. *ἐλαία (Min.)* An olive-green variety of chrysolite], constitutes by far the greatest bulk of the rock, and occurs in well defined crystals,‡ which are usually sur-

* Loc. cit., pp. 506, 507.
† Loc. cit., p. 507.
** Loc. cit., p. 507.
‡ See Analytical Chart.

rounded by the green decomposition product, or enclosed in the crystals of augite. The sections of these crystals generally present elongated six-sided forms, although eight-sided and four-sided ones are by no means uncommon, and in some instances their outlines are altogether irregular, their angles also may sometimes be seen to be rounded off. Those enclosed within the augite are, as a rule, of small size, but are nevertheless very clearly defined, they range in length from ·0047—·0458in., and in breadth from ·002—·003in. The other larger crystals have a length of from ·120—·037in., and a breadth of ·039—·031in.* It has been observed that whilst the length of the crystals varies very largely their breadth seems to assume more constant dimensions. A few of the crystals have become changed to a reddish brown colour, and some of these may be seen under a power of about 100 diameters to exhibit a faint striation, and bear out the statement made by DANA† who attributes this change to the oxidation of the iron in the mineral, which is accompanied by a modification of its colour to a brownish or reddish-brown, may become iridescent, and split into laminæ, so as to resemble a mica. But the vast majority of the crystals are traversed by irregular fissures, which do not bear any relation to their crystallographic forms, but seem to be altogether indefinite. It is evident that the greater number of these cracks have been produced during the slicing and grinding of the section; but, at all events, there are others which have not been thus caused, and may be recognised by the alteration which has taken place along their lines.

This change is seen to progress from the fissures into the substance of the crystal, and to superinduce a finely fibrous fringe at right angles to the lines from which they radiate, and the part so altered exhibits a honey-yellow colour. The borders of the crystals also become the seat of a similar change, and acquire a colour ranging from honey-yellow to a dirty green. Under powers of from 300 to 500 diameters these serpentinous fissures are shown to be filled with a material of a brownish yellow colour, in which numerous minute acicular and granular opaque black microliths obtain, and are probably composed of titaniferous iron or magnetite. Minute spaces may also be seen here and there, but they are either empty or filled with gas. Fluid cavities do not occur in this olivine, and the cut surfaces of the crystals appear quite coarse and rough under a high power of the microscope. Under crossed Nicols the fresh portions of the crystals polarise in strong colours, and are doubly refractive, the altered parts continue unchanged throughout the rotation of the prisms.

The alteration products which surround most of the crystals of olivine vary in tints from a bright grass green to a rich emerald hue discoloured every here and there by a dirty brown or reddish brown which probably results from the decomposition of the iron both of the olivine and the titanoferrite. These limonitic discolourations may be seen surrounding many of the crystals of iron, and thus lead us to suppose that it is the

* These, and all other measurements given in this paper on the authority of the writer, admit of extremes on both sides, and especially for the crystals of olivine enclosed within the augite, which may be reduced to mere granular specks, even under a high magnifying power. In all cases they have been selected from over 300 accurate estimates.

† A System of Mineralogy, London, 1881, 5th ed., p. 258.

result of their oxidation which gives rise to the brownish patches in the green groundwork. With a power of about 500 diameters every portion of this green material seems to be crowded with peculiar tufted fibrous structures, which radiate from centres of growth as it were, and in some portions small groups of minute colourless prisms are aggregated together which remind us strongly of the similar larger prisms of apatite which abound in these parts of the field. That the green substance is an alteration product of the olivine is easy to imagine, since the crystals of olivine may be seen to be insensibly invaded by it, both through their borders and by way of the serpentinous fissures already alluded to, and the investigations of DANA, to which we have already referred, warrant us in stating that the iron of the olivine, after having been oxidised, has been removed by the action of carbonated waters together with some of the magnesia, and that the result of this reaction has manifested itself in the formation of this green fibrous material, which we consider to be true serpentine. Our conclusion is, moreover, supported by the fact that we have detected a precisely similar texture in the undoubted serpentine of Clicker Tor in Cornwall, and in a beautiful specimen from Saxony, both of which bear traces of being the metamorphosed results of a rock allied to lherzolite. The green material polarises very feebly, the fibrous tufts become illuminated by pale bluish and grey tints, whilst the ground substance remains dark, phenomena which also obtain in the serpentines.

The AUGITE, (*a*) *n.* [Fr. *augite*, Lat. *augites*, Gr. αυγιτες, from αυγε, brightness.]

Next in abundance to the olivine, occurs as singularly fresh large crystals in irregular, angular, and subangular patches, with numerous longitudinally disposed parallel breaches, which impart a coarsely lamellar aspect to the mineral, and a multitude of indefinitely disposed cracks, resembling the fissures produced in a broken pane of glass, and evidently due to the mechanical methods of manipulation, occasionally well marked eight sided forms may be seen. The crystals average in length from ·025—·083in., and give good cleavage angles of 87° 5′, and 92° 5′; their boundaries are in every case very sharply defined, and they vary from a pale claret tinge by occasionally shading off to an edge of purplish-brown and yellowish-brown. Besides the crystals of olivine they do not possess any enclosures, unless we regard a few minute rhombohedra and acicular and granular particles of iron as such, but these are always closely contiguous, if not embraced within the endomorphs of olivine; these last exhibit all the details of the larger crystals which we have already fully described. The appearances we have noted, and the absence of any zonary lines of accretion, or of any modification in places where it is in contact with the highly metamorphosed greenish fibrous serpentine, altered chloritic product, or other decomposed constituent, lead us to surmise that the crystallisation of the augite must have been the final phase in the formation of the rock texture.

With polarised light under a power of 70 diameters, most of the crystals are seen to be very feebly dichroic, and appear perfectly dark under fully crossed Nicols. A few of them, however (by no means thick sections) are strongly dichroic, changing from a brilliant azure blue through a rich purple and neutral tint to a golden orange under com-

pletely polarised light. One specially thin section did not exhibit the purple coloration, but changed from a delicate blue through neutral tint to a pale orange. Examined under ordinary light, we are predisposed to detect a slight excess of yellow and purple in these augites, and thus to add evidence to the generalisation arrived at by ALLPORT in his extended observations on this mineral in his admirable memoir.*

A whitish milky decomposition product, with obscurely parellel lines, fills most of the interspaces between the olivine, green product, and the augite; it is crowded with a meshwork of cracks, around which a high power reveals a finely granular cloudy texture; it does not contain any endomorphs or cavities. Other similar aggregates of a finely granular aspect seem to merge gradually into certain patches of the green serpentinoid material, and a few brownish white fibrous tufts may be seen filling up some of the cavities, and are probably of a zeolitic nature for they exhibit a dark cross between crossed Nicols, and the cross remains stationary on a horizontal rotation of the section. The white decomposition product is unaffected by polarised light except in certain places where indefinite parallel bands of colour appear, and seem to indicate the vestiges of what once was a felspar exhibiting twin lamellation.

TITANIFEROUS IRON, *(t)*.—TITANIFEROUS, *a* [N. Lat. *titanium*, so called from the Titans; Lat. *titani*, or *titanes*, Gr. Τιτᾶνες, the sons of the earth, and Lat. *ferre*, to bear; Fr. titanifère]. Containing titanium. This mineral occurs in the form of occasional large broken plates, in the section, which bear traces of an hexagonal form and numerous well marked small rhombohedral sections, varying in size from ·033—·0024 in. The larger plates are situated chiefly between the crystals of olivine and the green matter, and never in the augite; the smaller forms abound in the same parts, and also obtain to a less extent within the crystals of olivine, always, however, at the lines of fissure of yellow or green alteration product, and especially in those portions which encroach on the borders of the crystals; rarely in the white decomposition products, and only exceptionally in the augite, and then, as has already been pointed out, immediately contiguous to the enclosures of olivine. They are perfectly black and opaque and exhibit a dull metallic lustre when viewed under condensed and transmitted light at the same time. Polarised light, of course, is not of much value here; we may note in passing, however, that a few of the crystals in one of the sections examined, had either undergone some change, or what is more probable had been ground so excessively thin, that they appeared of a reddish brown colour by transmitted light, and became alternately opaque and translucent with polarised light, some being brilliantly lighted under crossed Nicols and others quite obscure, whilst on a revolution of the polariser the illuminated ones gradually became black and then suddenly resumed their ordinary hue, and the obscure ones were rendered apparent. We say that it is probable that these crystals had been ground very thin, because they preserve their hexagonal contours with wonderful distinctness, and in one case we observed the opaque black part passing gradually to the translucent reddish portion. Very many of the iron crystals are surrounded by a reddish discolouration; in some of these

* On the microscopic structure and composition of British Carboniferous Dolerites, Q J. Geol. Soc., Vol. xxx, p. 536.

cases they seem to be partially decomposed, and may give rise to this reddish appearance, but the immediate contact of these with partially altered olivine crystals leads us to attribute it to limonitic discolourations produced by the oxidation of the iron in the olivine, and we are supported in this conclusion by the fact that the iron crystals seem to be in beautiful preservation, and moreover the greyish white decomposition product which so often accompanies the breaking down of titaniferous iron is wholly absent here.

MAGNETITE, (*m.*) *n.* [Lat. *magnes, magnetis*, Gr. Μαγνὴτης, or Μαγνῆδιος, *i.e.*, Magnesian stone, from Magnesia, Gr. Μαγνησία, a country in Thessaly; or according to PLINY, from MAGNES, who is said to have discovered it from the attraction of his shoe nails, and the iron ferrule of his staff to the ground over which he walked]. MAGNETIC IRON ORE. A very few lozenge-shaped and squarish opaque black and rarely semi-translucent reddish forms, which are probably sections of magnetite crystals may reward a careful search, but all doubts as to the occurrence of that mineral seem to be removed with the use of a moderately high magnifying power (300 diameters) with which perfect little octahedra, acicular, oblong, and granular irregular microliths may be seen in the serpentinous strings of green and yellow matter in the olivine, and amidst the green decomposition patches

BIOTITE, *b. n.* [So called after BIOT], occurs in elongated narrow scales, and shorter broad plates, chiefly in the green serpentine and decomposed parts, and at the edges of the white decomposition products. The scales vary in length from ·0149—·0055 in.; and in breadth from ·0049—·0009 in. and are all markedly striated in a longitudinal direction. In thin sections they are all of a uniform delicate pinkish brown tint, but in thick sections become rich brown. Under a power of 500 diameters their ends seem to be frayed out, but many of them show clean cut edges. A few of the crystals are dichroic, but most of them appear dark, or preserve their ordinary colour, when illuminated, between crossed Nicols, and these are probably cut parallel to their basal planes. Wherever the biotite is found, it may be observed that two or more, often five or six, of the crystals lie near to one another. We have not found any isolated examples.

APATITE, (*ap*) *n.* [From Gr. ἀπάτη, deceit, ἀπατᾶν, to deceive. So called because the older mineralogists were very often deceived by its appearances, mistaking it for aquamarine, chrysolite, etc]. With a power of about 50 diameters there may be seen, in certain of the green patches, a few colourless, rectangular, narrow, but greatly elongated minute crystals, with here and there a small pellucid hexagonal section. In length they measure from ·033—·0093 in., and in breadth from ·0037—·0024 in. That these are crystals of apatite there cannot be the least shadow of a doubt, for with higher powers and the use of polarised light their true nature may be clearly demonstrated. We have directed attention to the fact that only *some* of the green patches of serpentinoid matter are invaded by these beautiful prisms; we may further state that *most* of the patches of green are devoid of them, nor do they obtain in other parts of the field. They are usually in groups of many crystals, and rarely as isolated forms. With a power of 100 diameters we may note that each rectangular elongated section exhibits transverse dislocations at

EXPLANATION OF PLATE.

Fig. I. × 25.

O. Olivine, serpentinised, but still comparatively fresh.

O' Olivine with edges rounded off, supposed by some to be due to a secondary fusion.

O" Olivine which has undergone considerable alteration. The iron has been oxidised, and the whole crystal form filled with the hydrous result. At the bottom of the plate O" shows a further superinduced fissile structure.

Ol. Endomorph of olivine within the augite.

S. Serpentinoid, green alteration product; exhibiting occasionally a rectangular grating-like fibrous texture, as well as a meshwork appearance; probably due to the metamorphosis of enstatite as well as olivine (Rosenbusch).

Au. Crystal of augite, obscurely octagonal.

W. Whitish crystals and decomposition products, probably forms of massive enstatite and phases of its primary alteration in addition to other pale associated aggregates.

T. Plates of titaniferous iron. A little below the iron at the bottom of the illustration two minute granules and a small hexagonal section of the same mineral are shown.

B. Scales and plates of biotite.

L. Limonitic discolorations.

Fig. II. × 20.

Crystal of augite (a) with endomorphs of olivine (e, e', e"). olivine (e). olivine with rounded angles (e'). olivine only partially enveloped (e").

Fig III. × 695.

Scales and plates of biotite. (a), Elongated scale × 69·5. (b) Short broad plate × 69·5. (c), Frayed out end of a scale + 695.

Fig. IV. × 150.

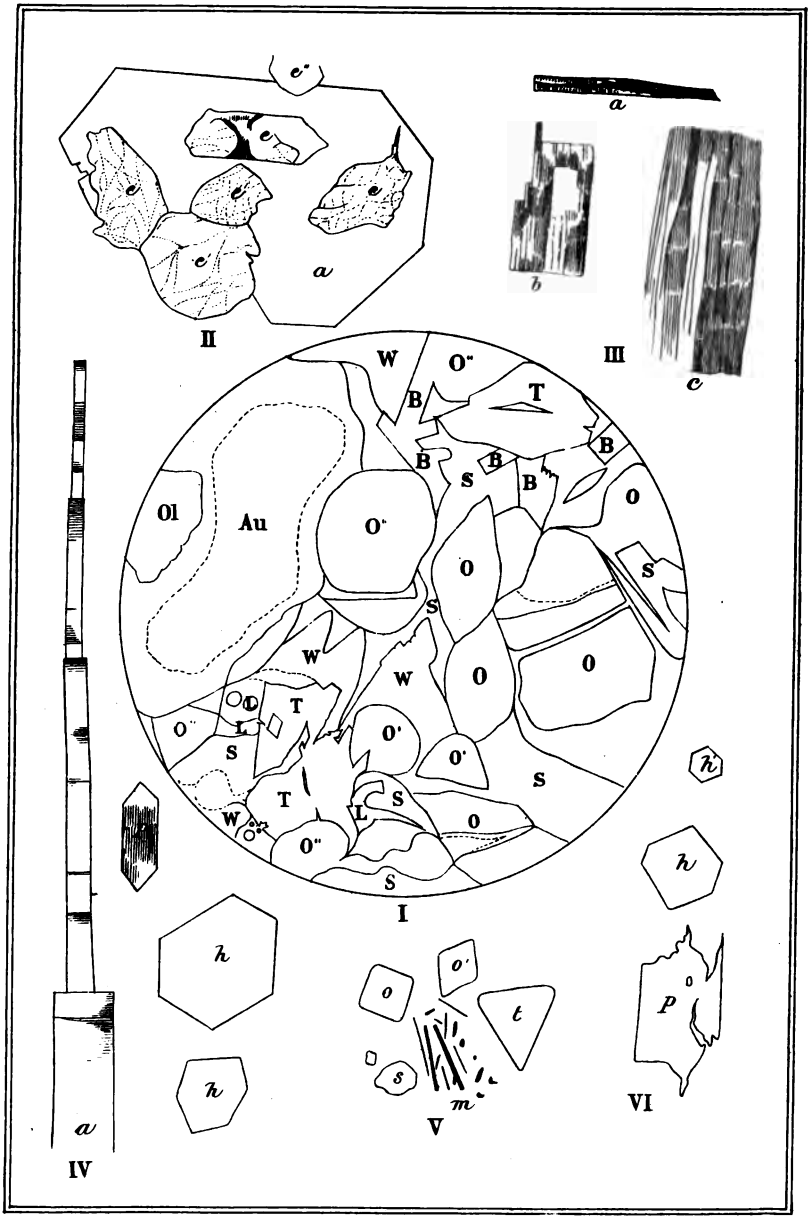
Crystals of apatite, (a), Elongated rectangular forms arranged in linear increasing series. (p), Short isolated prism. (h, h). Transverse hexagonal sections.

Fig. V.

Magnetite. (o), Square section × 150. (o'), Lozenge-shaped section × 150. (t), triangular section, with rounded angles × 150. (m), Microliths × 700. (s), Air or gas cavity × 700.

Fig. VI.

Titaniferous iron. (p). Plate somewhat broken × 25. (h), Hexagonal section × 150. (h'), Hexagonal plate × 695.



A. del. ad. nat.

J.W. Watson, del. et lith.

PIKRITE

Analytical Chart.

Watson & Son, Chromo Lithogrs, Newhall St, Birm.

intervals, and that many of the crystals which appeared under the lower power to be enormously elongated and tapering, are in reality a longitudinal arrangement of gradually diminishing members. A power of 500 diameters brought to bear upon *most* of the green patches, and especially upon those containing the apatite prisms, is almost starting in its revelations; there may be seen little isolated stellately arranged groups of excessively minute colourless somewhat flattened prisms radiating from centrally situated ones, and at the borders of the green product multitudes of these little crystals project outwards into the green ground from separate centres; similar isolated prisms are scattered about at intervals, and a host of acicular clear glassy particles of various sizes may be detected. That all these structures are apatite crystals is doubtful, yet from analogy and their mode of occurrence it seems plausible at least to regard them as such, for they are of similar shapes, and exhibit the same colour as the larger crystals, and what is more important they obtain in greatest abundance immediately around the larger crystals, the hexagonal sections of which are literally surrounded by them. Between crossed Nicols the longitudinal rectangular sections may be still clearly discerned, but the transverse hexagonal ones become perfectly dark and obscure. The minute prisms we have described are too small to admit of the analysis of polarised light, and even if they could be seen the result would be vitiated by the interposition of the green matrix in which they are situated.

In our illustration, which shows a section of the rock, magnified 25 diameters, a large, irregular crystal of augite, of a pinkish-yellow colour, is shown with an enclosure of olivine. At the right hand side may be seen three well defined crystals of olivine, partially serpentinised; between these and the augite, a little above the centre of the picture towards the left, a crystal of olivine is shown, with rounded angles. The green colour indicates the serpentinoid alteration product, and the grey shows the position of the white altered material. At the top of the field, five scales of rich brown biotite are shown, and between the black crystal of titaniferous iron at the top, and the long scale of biotite, a dark brown plate of olivine, which seems to be a pseudomorph of limonite, is depicted. The apatite is not shown; indeed, it can just barely be detected under such a low power. The magnetite, of course, cannot be seen at all with a magnifying power of 25 diameters.

In the first portion of this description, we detailed, briefly, some of the characteristics of other igneous rocks, which are usually classified, with pikrite, as rocks of exceptional mineral constitution. We did so, because it is our desire to point out that this little group of igneous rocks in the character which they possess in common, of foreshadowing serpentine, admits of a thoroughly rational classification. And this is an opportune moment for us to introduce an innovation in the nomenclature of rocks, which if fully carried out by competent mineralogists, would, we believe, be the foundation of a strictly scientific classification. Thus, under the head of *serpentinogenic* rocks we may form two groups, an *igneous* and an *aqueous* (?). These groups may be divided into genera, and the genera into species. Thus, in the igneous group we would have the genus Llherzolite, Dunite, Pikrite, etc., and the genera may be divided into species from the localities in which they are found, the

mode of their occurrence, from some exceptional or predominating constituent, peculiar texture, or other more or less cogent reason, and a generic as well as a specific name thus applied to each and every rock to distinguish it from all other rocks; and in this way a system of petrology might be built up which would vie with those of the biological sciences.

METHODS OF PREPARATION.

It is only within comparatively recent times that the compound microscope was first applied to the investigation of the minute structure of minerals and rocks. Anatomists and chemists were long familiar with the instrument, but the mode of preparing hard sections by mechanical methods for examination under the microscope was not introduced until WITHAM, in 1831, published his researches on the internal structure of fossil plants*. To NICOL, of Edinburgh, however, belongs the honour of having invented that process, and we are told on the authority of SORBY† that NICOL prepared the specimens and wrote the description of his processes for WITHAM's book. BALFOUR‡ also describes the method as that of NICOL. In his researches on the comparative anatomy of the teeth OWEN, and in his study of the dental tissues, NASMYTH employed similar means for obtaining hard thin sections, and CARPENTER§ first applied the method in revealing the minute structure of recent shells.

Up to this period mineralogists were wont to employ the time honoured simple lens in their observations of the intimate structure of minerals and rocks. It is true that in 1838 DUFÉRNOY ** used the microscope in his examination of volcanic ashes, but then he did not cut sections of the rocks, nor did he carry his researches any further, and this state of affairs continued until SORBY†† in 1858 communicated the results of his microscopical analyses of minerals and rocks to the Geological Society. This was the commencement of the study of a branch of lithology, which in the short course of twenty-four years, has assumed such vast proportions, that it is fully entitled to rank as the chief department of mineralogical science. The example set by SORBY in this country, and supported later on by DAVID FORBES *‡ was ardently followed by their continental contemporaries, and it is especially due to the indefatigable labours of the German mineralogists that microscopical lithology has assumed its present elaborate form. The German school was founded by F. GIRKEL who published his first paper entitled *Mikroskopische Untersuchung von Gesteinen und Mineralien**§ in 1863, and this, his subsequent work, and HERMANN

*_Observations on Fossil Vegetables_, by H. WITHAM, Edinburgh and London, 1831.

†_Preparation of Transparent Sections of Rocks and Minerals_, by H. C. SORBY, A Paper read before the Sheffield Microscopical Society, March 3rd, 1882. See _The Northern Microscopist_, London, May and June, 1882.

‡Class Book of Botany, by J. H. BALFOUR, Edinburgh, 1870.

§_Report on the Microscopical Structure of Shells_, Rep. Brit. Assoc. 1848.

** _Annales des Mines_, 3e Série, Tome xii, p. 355.

†† _On the Microscopic Structure of Crystals indicating the origin of Minerals and Rocks, Q. J. Geol. Soc._, London, 1858, Vol. xiv, pp. 453-500.

*‡ _The Microscope in Geology, Popular Science Review_, Vol. vi, 1867. pp. 355-368.

*§ _Verhrndhand der k. k. geologischen Reichanstalt_, Jahrgang 13, s. 8.

VOGELSANG's memoir published in *Poggendorf's Annals** followed shortly after by his *Philosophie der Geologie*† attracted workers from all parts of the world into this field of inquiry. In Germany a long list of illustrious names support those of ZIRKEL and VOGELSANG; amongst these we may more especially mention H. BEHRENS, E. BORICKY, E. COHEN, H. FISCHER, C. W. C. FUCHS, C. W. GÜMBEL, G. A. KENNGOTT, KOSMANN, AVON LASAUBX, H. LASPEYRES, H. MÖHL, G. VOM RATH, G. ROSE, H. ROSENBUSCH, F. SANDBERGER, A. SCHRAUF, A. STELZNER, A. STRENG, G. TSCHERMAK, and C. E. WEISS. In France much good work has been done recently through the contributions of CORDIER, DE LAMÉTHERIE, DESCLOIZEAUX, DUROCHER, FOUQUÉ, and LÉVY. And lastly, in America and in this country ALLPORT, BONNEY, J. W. DAWSON, A. GEIKIE, HULL, RUTLEY, and others, have added very materially to our knowledge of the microscopical structure of minerals and rocks.

As the methods employed in the study of microscopical lithology depend very largely upon the physical properties of minerals and rocks, we often find it necessary to subject the specimen to a preliminary mode of treatment to enable us to slice and grind it into thin sections, but there are other means at our disposal often of as much interest to the biologist as to the petrologist. Thus, in the examination of the famous Barbadoes earth multitudes of exquisite siliceous tests of Radiolarians and Diatoms may be isolated by the judicious use of chemical reagents, aided by careful levigation. By a similar process in his researches into the London clay SHRUBSOLE brought to light myriads of beautiful Diatoms, encrusted with a coating of iron pyrites; and the same methods applied to volcanic ashes, clays, marls, and especially to glacial deposits, is often productive of a rich harvest of the more fragile forms of animal life, and the delicate remains of plants. In addition to all this the presence of mineral particles of exceptional occurrence or excessively minute forms, which would defy the utmost endeavours of the analytical chemist, yield most readily to this mode of observation, and often furnish evidence of extreme interest in the parageneis of the structure.

The method of pulverisation, in conjunction with that of levigation, comes opportunely to our aid in the study of the more compact rocks, and we have already noted that the application of the microscope to petrological research was first made use of in this direction by DUFRÉNOY. The residuum obtained by means of levigation, whether of pulverised hard and compact rocks, or of those of a softer and less dense texture, may be examined under the microscope dry or in water, or prepared as permanent objects in Canada balsam. Previous to mounting in the balsam, the powdered rock or washed deposit should be soaked for a few hours in turpentine or benzol in a small corked test tube; a portion removed by means of a pipette on to a thin cover glass, should be gently heated over a spirit or Bunsen flame until it is nearly dry and assumes a sodden appearance, a

* *Ueber die mikroskopische Structur der Schlacken und über die Beziehung der Mikrostructur zur Genesis der Krystallinischen Gesteine, Pogg. Ann.*, xxi, 1864, pp. 101-124.

† *Philosophie der Geologie*, von. H. VOGELSANG Bonn, 1867.

drop of liquid balsam dissolved in benzol* applied to it, and laid aside for a few hours in a suitable tray, protected from dust; another drop of balsam may now be placed on a clean glass slip and gently heated, and the cover glass with the object upon it carefully lowered on to the balsamed slip. If these precautions are taken, and the exact quantity of balsam used, which a very little practice will determine, the preparation will be found to be perfectly mounted with a clear bevelled rim of the medium solidified when dry into a sloping edge.

In a future article we shall detail the special methods of pulverisation and levigation as applied to the requirements of typical deposits and rocks, such as the isolation of siliceous organic forms, and the separation of calcareous tests and mineral particles.

THE METHOD OF PREPARING THIN SECTIONS OF MINERALS AND ROCKS.

Most minerals and rocks when perfectly fresh admit of being cut and ground down into thin sections without any previous mode of treatment, but there are very many which would break into small fragments or crumble to a powder, if we attempted to handle them under such circumstances; as examples we may mention the fibrous varieties of pyroxene, shales and schists, clays and marls, soft chalks, and most weathered rocks.

PRELIMINARY.—All minerals and rocks whose texture does not permit of mechanical treatment should be procured in the form of small chips or fragments, or, where it is possible, in slices ranging from one-half to one-eighth of an inch in thickness. In the case of glacial clays and soft chalks, and all rocks which in their natural state are usually gathered with a large quantity of water in them, they should be gradually dried, but not heated to such an extent as to cause them to crumble away on being touched; immersion for a short period in methylated spirit will render them suitable for the next operation, which consists of soaking them in turpentine for a time varying from a few minutes to several hours, until they are thoroughly saturated. The next process consists in applying a quantity of hardened Canada balsam to them, and may be best accomplished thus:—A quantity of balsam placed in a sand or water bath, or subjected to gentle heat, should be tested from time to time by removing a small drop with a glass rod; as soon as the balsam shows a tendency to become hard on cooling, the turpentine soaked specimens may be placed in it and the heating continued until they are thoroughly impregnated with the hardened balsam; they may then be removed and laid aside until quite cold. A primitive mode of carrying out this process is to place the balsam unhardened on the turpentine soaked material, to lay it aside in a warm place, and to repeat the operation until it becomes hardened, but this is a most unsatisfactory plan, and at best but a slovenly method. A solution of shellac in spirits of wine or of Canada balsam in chloroform or benzol may be used instead of hardened balsam, but neither of these are so uniformly successful in their application. Thus prepared the specimen may be cut into slices.

* The successful mounting of objects in Canada balsam depends very much on the purity and consistency of the medium. Wherever we recommend the use of balsam, we desire it to be understood that hardened balsam, which has been dissolved in pure benzol, and filtered once or twice till it is moderately viscous, should be used.

1ST PROCESS.—*Cutting the slices or procuring chips.*—Where practicable it is always best to secure large fragments of rocks, from three to five inches square, and to chip or slice them afterwards at leisure; but this cannot always be accomplished, and in that case chips should be taken in the field. A sharp blow with the edge of a geological hammer* will with a little practice enable anyone to detach a sufficiently thin and large chip. Mr. RUTLEY in his small volume "*On the Study of Rocks*" gives the following directions for obtaining chips from minerals and rocks, which we have found a most useful method:—"As it is desirable to lessen the labour of grinding as much as possible, the first thing to be done is to procure a thin chip or a thin slice of the mineral or rock about to be examined. A square inch is a convenient size for the chip or slice, as such a piece will often undergo considerable diminution before it is reduced to a sufficiently thin state. Chips may be procured by using a small hammer, but frequently a number of flakes have to be struck off before one of suitable size, thinness, and flatness is got. When the specimen is very small, and difficult to hold in the hand while the hammer is used, a satisfactory chip may often be procured by holding the fragment in a suitable position on the edge of a cold chisel either let into a block of wood, or screwed into a vice, but then the operator must take care of his fingers. In the chipping of very hard rocks, it is also advisable to protect the eyes, especially when the hammerer is not well practised in stone breaking. For this purpose a pair of wire gauze spectacles will be found useful. When cleavable minerals are to be dealt with, it is best to avail oneself of the cleavage, but also to note in which direction of cleavage the plate is struck off, and, if it be desirable to make a section in some other plane than that of cleavage, a slitting or sawing process hereafter to be described, is the only way in which such a section can be procured."

The slicing of minerals and rocks may be accomplished either by hand or with the use of a suitable machine. Hand slicing, when applied to substances whose hardness exceeds 5 or 6, is apt to become very tedious; it may be effected by the use of a toothless framed saw of soft iron, charged with fine flour emery and water, or a bow made of bamboo or some other pliant, yet strong material, with a string of soft iron wire and similarly charged may also be used.**

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* The form of hammer devised by PROFR. A. GEIKIE, and known as the "*Geological Survey*" pattern is very useful for this work. For general purposes however a tolerably heavy hammer with a head of Swede-iron with well tempered steel ends welded on, is recommended by Mr. RUTLEY. One end of the hammer head should be square, and the other ought to taper to a wedge with an obliquely decollated extremity. The eye into which the handle is fitted should be at least 1⅛in. in length by ½in. in breadth, and filed away slightly round its under opening to reduce the chance of snapping the shaft. The latter should be made of some tough wood, preferably ash, free from knots or flaws, and thoroughly well seasoned; it should moreover be as thin as it can conveniently be made, and tightened in the eye of the head by means of a small iron wedge inserted into a slit at its upper end. A few of these wedges should be carried in a pocket lined with soft leather (an admirable form of geological bag) to guard against mishaps, and if the handle snaps, which usually happens immediately below the head, a strong pen knife will be found serviceable provided the shaft is long enough; it is well to have the shaft at least 13 inches, and better still to use one 24 inches in length.

** For this method we are indebted to MR. H. HENSOLDT, of Wetzlar.

Numerous slicing and grinding machines have from time to time been constructed, ranging from inexpensive worthless toys to elaborate amateur's lathes. We cannot, however, recommend any of these instruments as at all approaching in excellence of working qualities the cumbersome, yet effective lapidary's bench, the value of which has been determined by the experience of generations of able workmen, whose utmost endeavours have been exerted in the production of a machine to enable them to maintain their stand in the struggle for existence.

The working lapidary provides himself with a strong heavily made table about 3 feet in height, 3 feet 6 inches in length, and 2 feet in breadth. The top of the table is divided into two tray-like compartments, with ledges 6 inches in height; one of these divisions is 2 feet 4 inches by 2 feet, and the other 1 foot 2 inches by two feet in size. The centre of the larger of these compartments is bored by an aperture, through which the axle of a very heavy iron fly-wheel, placed horizontally, is made to pass, and to terminate above the table in a handle secured by a nut, and by means of which the fly-wheel can be set in motion; the lower end of the axle is pointed, and revolves upon a bearing of lignum vitæ.* The smaller compartment, also, has a central aperture, through which a spindle carrying a lap or disc 9 inches in diameter is passed; it revolves both above and below between lignum vitæ bearings, but the upper bearing may be made of steel, and can be adjusted by means of a nut from above. A leather strap, or hempen thong, is placed around the fly-wheel, and a grooved, enlarged portion of the spindle on a level with the fly-wheel, and both are thus made to revolve by turning the handle of the fly-wheel. Close to the edge of the lap a vertical iron rod, encased in a movable piece of wood, is fixed; the wood is pierced by a number of holes at stated intervals, into which pegs may be placed at will at right angles to the rod and at any height above the lap; these pegs form extemporaneous rests for the hand whilst holding specimens which require to be ground at certain different angles, as in the production of facettes on precious stones, and is called a "*gimp peg.*" A can of water or of oil, with a regulating tap for dropping the liquid near to the edge of the slitting disc, or on to any portion of the surface of the lap, may be fixed in a convenient position by means of a bent arm, fastened to the top of the table or to the support which holds the upper bearing of the lap spindle.

The dimensions given above are specially adapted to petrological work. One splitting disc and four laps are also necessary, each one fitted on to its own spindle. The splitting disc is made of a circular thin sheet of soft iron, tinned plate is often used. In slicing the mineral or rock, the edge of the disc should be charged with diamond dust, made into a paste with a little sweet oil; a very small quantity applied to the edge with a brush or the finger, must be worked into the metal with a small glass roller. The fragment to be sliced may either be held in the hand, or fastened by means of red cement or elastic glue, to a block which

*Working lapidaries always use lignum vitæ instead of metallic bearings, as the latter are apt to induce a slight springy motion to the lap, which would be fatal to the production of true facettes on gems. Such lignum vitæ bearings, if properly used, ought to last for two or three years unimpaired, and then they can be readily renewed.

can be pressed steadily against the rotating disc ; great care must be taken in doing this to keep the edge of the slicer well lubricated with oil-of-brick, or soft soap and water, and in commencing the operation the part of the fragment first operated upon should be deprived of any sharp angles it may happen to have by means of an old iron file or a jeweller's emery file. If these precautions are not taken, the diamond charged edge will inevitably be stripped off.

2ND PROCESS.—The chip or slice of rock procured, must next be ground perfectly flat on one side and then polished ; this may be done either by hand or on the grinding bench. If by hand, four plates should be procured, each about 15 inches square ; two of lead, zinc, or better still of lap metal, one of pewter, and one of plate glass. The chip or slice must be ground perfectly flat on one side, with moderately fine emery on one of the lap metal plates, then with still finer emery on the second lap metal plate, and the process repeated with flour emery on the pewter plate ; it should next be polished with jeweller's rouge, rotten stone or putty powder on the glass plate : between each change the slice should be thoroughly well washed. The grinding and polishing should be conducted by a circular movement of the hand over all parts of the plates, to prevent the possibility of their wearing into hollows. The grinding bench should be furnished with four laps, made of similar materials, and used with the same substances as those noted for the plates ; the motion imparted by the left hand to the handle of the fly-wheel should be from left to right, and the slice or chip held in the right hand should be dragged backwards and moved forwards in a tangential direction, and from the circumference towards the centre of the rotating disc : this will prevent the irregular wearing of the lap, and accelerate the reduction of the section. The emery powder, which has been thrown off the disc into the tin tray, should be gathered after each grinding process, washed and re-collected for future use ; flour emery which has been treated in this manner five or six times, becomes eminently well suited to the production of a smooth flat surface when used on a piece of plate glass ; it is even preferable to the washed emery used by mirror polishers. It is not absolutely necessary to induce a high polish, all that is required is a perfectly flat and smooth surface free from scratches, and this can be secured with rotton stone* or putty powder even on the pewter lap ; red crocus (jeweller's rouge) is objectionable as a polishing agent, because it adheres so tenaciously to the specimen, and enters minute crevices, from which it is sometimes very difficult to dislodge it. Sometimes, especially with very thin slices or chips, it becomes very tedious to hold the section evenly on the grinding surface under the fingers, and the skin is apt to be worn away ; to overcome this the specimen may be fastened on to a small block of wood (an old cotton reel makes an excellent holder), and its position thus easily maintained. The shellac stick used by working jewellers is a good cement for this purpose ; it is sufficiently tenacious to hold the section firmly, yet brittle enough to admit of its immediate detachment with the point of a knife. Prout's elastic glue or Waller's wax may also be used.

* Rotton-stone should always be procured in solid pieces, the white variety is the best. It is also sold in the form of a powder, but this is prone to contain gritty particles, which would be fatal to the production of a smooth surface free from scratches.

3RD PROCESS.—The smooth or polished surface of the section must be fastened on to a piece of glass, and the other side reduced until the section is thin enough for microscopical examination. Most fresh mineral and rock sections can with care be removed from the slip of glass upon which they are finally ground to other clean slips, but there are many, *e.g.*, soft, friable, or greatly weathered rocks, which will not admit of such transference, and must be dealt with accordingly; of course they may be left upon the slips upon which they are ground, but then, as these are usually disfigured by scratches, it is desirable to adopt some other plan; a remedy may be found in the following process, which is a slight modification of that first employed by PHILLIPS. The smooth surface of the slice must be thoroughly cleansed by a slight soaking in benzol, just sufficient to remove all particles of rotten stone, rouge, or other material, but not so prolonged as to dissolve out the Canada balsam, with which the specimen has been impregnated, and fixed on to a circular piece of extra white thin glass, about one inch in diameter; this in its turn should be fastened on to an ordinary slip or piece of plate glass, and the reduction by grinding then carried on. When sufficiently thin the small circle of glass with the specimen attached to it can be removed on to a good clean slip, fixed there, and covered in the usual way. Fresh minerals and rocks, after having been ground thin enough, should be removed by a gentle heat with the aid of a small scalpel or other knife, into a watch glass or porcelain dish full of benzol, and thoroughly cleansed with a soft brush after a short soaking; a very little practice will enable one to take the section up on to the blade of a knife, drain away the adhering benzol, and mount it in Canada balsam under a thin cover.

To fasten the slice on to the glass, various cements may be used, amongst these we may mention Prout's elastic glue, transparent marine glue, a mixture of equal parts of resin and bees' wax, a mixture of bees' wax, gum dammar and Canada balsam, and best of all, hardened Canada balsam. For the sake of convenience the Canada balsam should be hardened by means of a water bath, or by a gentle heat, until it shows a tendency to become hard on cooling; whilst still warm it may be put up in the form of small pills, by dropping portions upon a cold plate or saucer, and rolling each drop into a pilule, or it may be moulded into the form of a rod or stick. A small portion of the balsam hardened in this way should be melted on an ordinary glass slip (some prefer a slip of plate glass), and the smooth surface of the section pressed upon it with a sliding motion, to the exclusion of bubbles of air; the superfluous balsam thus squeezed out must be scraped away from the slide before it has had time to solidify; if it is not removed it will form a very serious source of annoyance afterwards, by becoming a vehicle for particles of grit and emery powder, which may prove disastrous to the section in its final reduction, and if it is scraped off after it has solidified, such a process is apt to detach the specimen from the glass. It is not necessary to use a clip to hold the section in its place, for, when perfectly cold, the attachment of the specimen will be found to have been perfectly secured. The process of reduction may now be carried on with comparative ease, commencing with fine emery on the second lap metal plate, and finishing with flour emery on the glass disc until it has been ground so thin that

when examined under the microscope, the minute characters of the mineral may be identified, or the individual constituents of the rock are seen to lie side by side, and not one over the other; it may then be polished, cleared, and mounted. Some specimens require to be cut excessively thin, whilst the value of others depends upon their being cut only moderately thin; it thus becomes necessary to make constant use of the microscope to determine the exact moment when the section should be removed, and it is often useful to grind down one part of the section more than another; this is comparatively easy work, for the centre of the section, even when great care is taken and a perfectly flat grinding surface used, is usually thicker than the edges, sometimes disagreeably so. There is only one remedy for this, and that is to reverse the state of affairs; here a flat surface produces a slightly convex one. All that has to be done, then, is to use a slightly convex grinding surface to obtain an evenly ground section.

4TH PROCESS.—*Mounting the Sections.*—Place one or two drops of Canada balsam on a clean glass slip, and warm it gently over a spirit or Bunsen flame. A few air bubbles may rise to the top, but they are soon dissipated; remove the section from the benzol, drain it, and lower it on to the balsam gradually; place a drop of balsam on the top of the section, heat it slightly, and cover it with a thin glass which has been warmed. If the balsam has been carefully baked, the preparation may be cleaned and labelled as soon as it is cold.

In preparing sections of coal, and some of the softer chalks, clays, etc., neither emery nor any other powder should be used, as they become imbedded in the substance of the material or in the hardened balsam which holds the particles together. The slices ought to be selected from specimens free from cracks, and ground perfectly flat on one side on a slab of coarse slate, Welsh hone, or pumice stone, and polished on a fine grained Water-of-Ayr stone, Turkey stone, or Arkansas hone. They may then be fastened on to a glass slip with hardened Canada balsam, or transparent marine glue, and reduced by means of an iron file or corundum stick, finished off on the fine stone, covered with balsam and mounted.

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SPINAL CORD OF CAT.

T. S. Dorsal Region.

× 20.

Etymology.—SPĪ'NAL, *a.* [Fr. *spinal*, Sp. *espinal*, It. *spinale*, Lat. *spinalis*, from *spina*, the spine.] Belonging to the spine or back-bone of an animal. CÔRD, *n.* [Fr. *corde*, Pr., It., and Pg. *corda*, Sp. *cuerda*, from Lat. *chorda*, Gr. Χορδή, catgut, string, cord.] *(Anatomy)*, The *spinal cord*, *spinal marrow*, *medulla spinalis*, or *myelon*, is that portion of the cerebro-spinal nervous system which is contained within the *medullary* or *vertebral canal.*

DESCRIPTION.

Within the vertebral canal the spinal cord extends as a continuation of the medulla oblongata of the brain from the margin of the occipital foramen of the skull towards the caudal region, and in the adult condition may pass through the whole length of the spine, or come to an extremity at any part between the anterior thoracic region and the end of the tail. In man it ceases after reaching the lower portion of the centrum of the first lumbar vertebra, and is thereafter continued in the form of a thread like structure, termed the *central ligament*, or *filium terminale.* In the cat two very marked enlargements obtain in an otherwise slender cord; a *cervical*, which extends from the third cervical to the first dorsal vertebra, and a *lumbar enlargement*, which is situated at the last dorsal vertebra; after this it tapers gradually until it reaches the caudal vertebræ, whence it continues as the filium terminale. As in the case of the brain, the spinal cord is closely invested by a vascular layer of connective tissue, called the *pia mater*, and the delicate serous membrane, or *arachnoid*, is here continued from the cephalic region, in the form of a kind of sac, between which and the pia mater a fluid, the *cerebro-spinal fluid*, is contained. The dense periosteal membrane, or *dura mater* of the encephalon, is produced into a sort of sheathing encasement, which is considerably larger and longer than the spinal cord itself and is separated from the walls of the vertebral canal by a large quantity of areolar tissue, richly supplied with venous plexuses. The cord itself is held in position by ligaments, which attach it to its dura matral sheath, as well as by an anterior and posterior system of nerve roots, which pass from its surface towards the intervertebral foramina. At the lower extremity of the cord, the roots are very closely crowded together, and, instead of passing directly outwards to the intervertebral foramina, they take a parallel longitudinal downward course, forming lateral bundles known as the *cauda equina*, to pass out of the sacral foramina.

THE MEGASCOPIC CHARACTERS OF THE SPINAL CORD.—A rough dissection, to isolate the cord from its investing membranes, displays two very obvious fissures, which traverse its entire length, situated along

its ventral and dorsal aspects, and respectively termed the *anterior* and *posterior median fissures*. The anterior extends inwards to about one third of the depth of the cord, it increases in size from the cervical region towards the extremity, and is more distinctly marked than the posterior fissure. An involution of the pia mater, richly supplied with blood vessels, passes into the fissure, at the bottom of which a transverse band of white nerve fibres, the *anterior white commissure* may be seen. The posterior fissure is seen more distinctly towards the upper portion of the cord; a delicate septum of vascular connective tissue passes into it, but the pia mater merely dips into it as a sort of furrow; it extends towards the centre of the cord where it ceases at the *posterior grey commissure*. Besides these two median fissures there are two *lateral furrows* on each side of the cord, which are produced along the lines of attachment of the anterior and posterior roots of the spinal nerves. The posterior of these form a superficial depression on each side of the cord along the lines of attachment of the posterior nerve roots, but the anterior lateral furrows do not produce any marked grooves, because the fibres of the anterior nerve roots do not pass in as a compact bundle, as in the posterior roots, but are spread over a varying breadth. It thus happens that the external contour of the spinal cord exhibits itself in the form of a fluted column, with two primary and median anterior and posterior divisions separating it into two symmetrical halves, each half being in its turn divided into three more or less evident columns by the lateral furrows. The posterior surface of the cervical region is moreover marked by two indefinite longitudinal furrows, and a slender tract thus arises, which has been termed the *posterior median column*.

A further dissection of the cord, aided by the use of a simple lens, reveals the existence of a median longitudinal central canal, the *canalis centralis*, the remains of the primitive groove of the embryo. The anterior and posterior median fissures divide it into two lateral halves, which are connected by the comparatively narrow commissures which immediately surround the central canal, and a very definite arrangement of nervous elements can be made out. The ganglionic corpuscles are confined to the so-called *grey substance* which forms the isthmus and spreads out into two lateral masses, each of which sub-divides into an *anterior* and a *posterior horn*, and these are enveloped by the so-called *white substance*.

A transverse section of any part of the cord shows the grey substance in the form of two crescentic masses connected by the posterior or grey commissure; the convexities of the crescents are turned to each other in the antero-posterior median line, and both of them end in anterior and posterior horns. The anterior horn is short and broad, and spreads out towards the attachment of the anterior nerve roots, thus dividing the white substance around it into two indefinite columns; the bottom of the anterior median fissure is, moreover, separated from the posterior grey commissure by a band of white matter, the so-called *anterior* or *white commissure*. The posterior is usually longer and narrower than the anterior horn, it passes outwards to the posterior lateral fissure; its back part becomes somewhat enlarged and has been termed the *caput cornu posterioris*, whilst the neck like portion, which places it in continuity with the rest of the grey matter, is called the *cervix cornu*. The crown of the caput cornu

presents a peculiar modified semitransparent appearance, and is known as the *substantia cinerea gelatinosa* of ROLANDO; on the outer aspect of each crescentic mass between the two horns the grey matter sends out a network of processes which enclose portions of the white substance. The white substance forms the largest portion of the bulk of the cord, it surrounds the grey substance and is traversed by the median fissures already noted as well as by numerous trabeculæ of connective tissue which usually penetrate through it in an irregular manner, although in the cervical region a regularly disposed septum obtains which marks out the posterior median column.

REMAK and VALENTIN have noted that the extremity of the cord is entirely constituted of grey matter. Sections of other parts of the cord show that the grey in relation to the white matter obtains in greatest abundance in the lumbar, less in the cervical, and least of all in the dorsal region. An estimate of actual amounts shows a preponderance of white matter in the cervical, and of grey matter in the lumbar region. The forms of the grey horns also varies; in the cervical region the anterior are large and broad and the posterior narrow, in the dorsal region both are moderately narrow, whilst in the lumbar region both are very broad.

At an early stage in the development of the embryo a linear depression, the *primitive groove*, is formed on the surface of the blastoderm; on each side of this the epiblast is raised up by the growth of a mesoblastic ridge beneath it, until by the coalescence of the free edges of these two *dorsal laminæ* a cerebro-spinal canal is established. The thickening of the epiblastic layer thus enclosed, and its subsequent elaboration into nervous elements gives rise to the brain and spinal cord. In the osseous fishes *(Teleostei)* the involution of the epiblast results in the enclosure of a solid column of cells, which at a later stage of growth only becomes hollowed out in the spinal region to form its so called ventricle. Amongst the frogs, although the central canal of the cord is patent from the beginning, its elements exhibit a marked distinction into an outer layer of dark tegumentary cells, and an inner investment of an evidently nervous character. No such difference can be detected in birds or mammals; the layer of epiblast becomes greatly thickened laterally, whilst the anterior and posterior parieties remain thin; the consequence of this is, that a longitudinal slit is formed, and the primary central canal thus produced, divides into an anterior and a posterior portion by a union at the middle of the opposite surfaces. LOCKHART CLARKE* has shown that the lower of these divisions becomes the permanent central canal of the spinal cord, and that the upper one into which a prolongation of connective tissue from the pia mater passes, loses its canalicular character, and ultimately forms the posterior fissure.

THE MICROSCOPIC CHARACTERS OF THE SPINAL CORD.—The minute structure of the spinal cord is ultimately resolvable into three principal forms of tissue,—*epithelium*, *connective tissue*, and *nervous elements*.

The *epithelium* is manifested in the form of a single layer of ciliated cylindrical cells which line the cavity of the central canal, their attached

* *Researches on the Development of the Spinal Cord in Man, Mammalia, and Birds, Phil. Trans.*, London, 1862, Vol. 1.

ends are somewhat conical in form, and usually send filamentous processes into the tissues underneath them; they possess large well defined oval nuclei situated at their basal portions, and KLEIN* describes the occurrence of three or more large disc shaped particles in each nucleus, which the nuclei of the subjacent neuroglia possess in common with them, in addition to which he notes a delicate intranuclear reticulum.

The *connective tissue* forms a large portion of the substance of the cord; it forms a complete investment beneath the pia mater, and sends trabeculæ inwards, which divide and ramify until they merge into a peculiar delicate matrix in which the nervous elements occur, and to which the name *neuroglia* has been applied by VIRCHOW. Immediately around the central canal it occurs as an indefinite ring of a homogeneous gelatinous substance devoid of nerve tissue; it passes gradually on the one hand into the grey substance, and presents at certain parts a finely fibrillated appearance, whilst in contiguity with the central canal it is penetrated by the filiform processes of the epithelial layer, and by connective tissue from the median fissures of the cord, the nuclei of the connective tissue cells in this part closely resemble those of the epithelial cells, and the area thus marked out has been termed the *grey central nucleus*, the *gelatinous central substance*, or the *central ependymal thread*. The connective tissue at the tip of the *caput cornu posterioris*, and known as the *substantia cinerea gelatinosa* of ROLANDO, simulates the deeper portion of the ependymal tissue in being almost destitute of nerve elements, which only occur in the form of scattered fibres; it differs from the ependymal tissue in being very rich in cells. In the grey matter the connective tissue forms an excessively delicate reticulum which, when examined with a high power, presents a granular, spongy aspect, filling in the interstices between the nerve elements and blood vessels, and occasionally showing numerous oval smooth nuclei imbedded in a thin surrounding of undifferentiated protoplasm.

Many theories have been brought forward to explain its true nature, the most plausible of which seems to regard it as a delicate network of fibrillæ emanating from branched cells possessing nuclei from which the radiating fibrillæ arise as continuations of their intranuclear network. A transverse section through the white matter magnified about 350 diameters, shows a more marked condition of connective tissue than in the grey matter; large branched connective tissue cells, *neuroglia cells*, are seen intervening between the transversely cut nerve fibres, which are found to be imbedded in a sutentacular substance traceable to the connective tissue; every here and there a highly refractive dot indicates the position of an elastic fibril. The internervous substance thus constituted is found to be in direct continuity with the more massively developed trabeculæ of connective tissue which extend as branched networks from the more homogeneous band of obscurely nervous substance which is covered by the pia mater.

The *nervous elements* of the spinal cord consist of cells and fibres. The white substance is composed almost entirely of fibres, it possesses cells only in the immediate neighbourhood of the grey matter. The fibres vary in diameter from 1·69μ to 17μ, the largest are usually situated

**Atlas of Histology*, London, 1880, p. 101.

superficially, and the smaller ones more deeply, especially those near the inner angle, formed by the anterior and posterior cornua (KÖLLIKER). They are mostly disposed in a longitudinal direction, but are sometimes obliquely and occasionally horizontally arranged; on rare occasions they may be seen to divide, and the finer fibres often exhibit varicosities. Towards the periphery of the cord they are generally arranged in parallel lines; as they approach the grey matter, however, they often interlace. The oblique fibres are chiefly formed of the root bundles which pass outwards from the anterior and posterior grey horns; horizontal fibres occur as fasciculi in the posterior horn, and both kinds are found in the transverse commissures. On passing into the grey substance these fibres mostly become exceedingly fine, and form a delicate network amidst the connective tissue; those, however, which are connected with the nerve roots are arranged in bundles which take definite directions. The *nerve cells* of the grey matter may be roughly divided into two kinds—large branched cells, which vary in size from ·0634 – ·1269mm., and smaller ones, measuring from 8·466μ – ·0634mm. Towards the apex of the anterior cornu they form several dense clusters of very large *multipolar ganglion cells*, which vary very considerably in shape and size, and are sometimes pigmented with a brown substance; intervening between these are several large nerve fibres. Similar cells occur more sparingly throughout the grey substance of the anterior horn, and are generally of largest size towards its surface. At the base of the posterior cornu also, smaller cells exhibiting all the same characteristics, obtain. The processes of these cells may, according to DEITERS, pass into the trabeculæ of connective tissue of the white substance, or loop themselves around bundles of nerve fibres; DEAN, FREY, and REISSNER, also, state that these cells are occasionally connected by commissural processes, but other observers have failed to detect them, and DEITERS denies their existence. The processes of these cells are divided by DEITERS into two kinds, an *axis cylinder process*, which does not undergo any division, and becoming enclosed in a medullary sheath at some distance from the nerve cells is converted into a white nerve fibre, and one broad and many smaller branching *grey processes*. There are also some very delicate fibrillæ, which spring at right angles to the protoplasmic processes of the cells; these he has termed *secondary axis cylinders*. In the deeper portions of the posterior cornu, there occur examples of smaller nerve cells, of a somewhat fusiform shape; they resemble the ganglionic corpuscles already noted, in the possession of a small axis cylinder process, and a variable number of protoplasmic branches from which secondary axis cylinders proceed in directions at right angles to those branches. Another group of rounded ramifying cells of moderate size are aggregated at the base of the posterior horn, which are devoid of axial cylinder processes; their branches merely ramify through the substance of the grey matter, and enter into the formation of the complex system of fibrillar arrangements therein.

The true physiological significance of all these cells, and their processes is a question which is still unanswered, and the most conflicting opinions are held even amongst those who have devoted special attention to the subject. The *exact* relations of these cells to one another, and to their surrounding elements throughout the whole of the spinal cord up to the

brain, yet remains to be investigated before any definite functions can be assigned to them, and our present state of knowledge in this department leaves us where it left HALL in 1837, with the broad generalisation that *it is probable that the mode of origin of the nerves of sensation is distinct from that of the nerves of motion.*

BLOOD VESSELS.—The spinal cord is very richly supplied with blood vessels; a large delicate capillary meshwork is formed in the white substance from the vessels of the pia mater which enter the cord along with the trabeculæ of connective tissue. The grey substance derives a very dense capillary system, especially in the neighbourhood of the ganglion cells from three twigs, two of which lie in the anterior and one in the posterior fissure, and belong to the anterior median spinal artery. The capillaries thence pass to two specially large veins close to the central canal. All the blood vessels are more or less invested with a layer of connective tissue, between which, and the enclosed vessels HIS has described a *perivascular system*, supposed by some to be lymphatic.

METHODS OF PREPARATION.

It is absolutely necessary where sections are desired, to subject the spinal cord to some hardening process. Any of the six following methods may be employed with success.

(i.) CHROMIC ACID.—The cord with its attached pia mater, should be cut into pieces about half-an-inch long, and placed in three times its bulk of a quarter per cent. watery solution of chromic acid; the solution should be changed at the end of eighteen hours, and at the end of three weeks rectified spirit or good methylated spirit substituted; in about two or three weeks it will be ready for cutting into sections. This method was employed in the preparation of the specimens, from which the illustration was taken.

(ii.) SPIRIT AND CHROMIC ACID.—Place pieces half-an-inch long in rectified spirit in a cool place for eighteen hours, transfer to a quarter per cent. watery solution of chromic acid for eighteen hours, renew the fluid, and, at the end of six or seven weeks, retransfer to spirit until required.

(iii.) CHROMIC ACID AND SPIRIT MIXTURE.—Dissolve one gramme chromic acid in 20 CC. distilled water, and add it slowly to 180 CC. spirit, allow it to become cold before using. Into this place half inch pieces for from two to three weeks, transfer to spirit until required.

(iv.) SPIRIT AND IODINE MIXTURE, AND AMMONIUM BICHROMATE.—Place the cord in a long glass tube of rectified or methylated spirit made slightly brownish with tincture of iodine for three or four days, or until the iodine colour has vanished. Cut into pieces about half an inch long and place them in three times their bulk of a two per cent. watery solution of ammonium bichromate for four or five weeks, transfer to spirit until required.

(v.) POTASSIC BICHROMATE.—Place half inch pieces in a two per cent. watery solution, each piece should be wrapped in a small quantity of cotton wool, previously wetted with the fluid. A large quantity of the fluid should be used, and should be changed once or twice during the three or four weeks which it takes to harden. Transfer to spirit until required.

(vi.) MÜLLER'S FLUID AND SPIRIT MIXTURE AND AMMONIUM BICHROMATE —For Müller's fluid, dissolve twenty-five grammes potassic bichromate and ten grammes sodium sulphate in 1,000 CC. distilled water, to three parts of this add one part of rectified or methylated spirit, and allow it to get cold. Place large pieces in this for twenty-four hours in a large quantity of the fluid and in a cool place, change the fluid at the end of a week ; the cord should now be cut into half inch pieces, and these allowed to harden for three weeks, transferred to a two per cent. solution of potassium bichromate, for two weeks, and then into spirit until required.

The hardened pieces may be imbedded in paraffin, carrot, or frozen in a strong solution of gum, and cut into sections. They may be stained in log-wood, carmine, or an aniline dye, preferably in a one per cent. solution in distilled water of aniline blue-black. For methods of staining and mounting, see this journal, pp. 6, 40.

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HUMAN LIVER.

V. S. Stained Logwood.

× 233·3 diameters.

l. Hepatic cells, *v.* Interlobular vein, *a.* Artery,
b. Bile duct, *c.* Capillary space.

Etymology.—HŪ'MAN, *a.* [Lat. *humanus*, from *homo*, man; Fr. *humain*, Pr. *human*, *uman*, Sp. and Pg. *humano*, It. *umano*]. Belonging to man or the human being.

LĬV'ER, *n.* [A-S. *lifer*, Icel. *lifur*, Sw. *lefver*, Dan. and D. *lever*, O. H. Ger. *lebara*, M. H. Ger. *lebere*, N. H. Ger. *leber*.] *(Anatomy)*,—The largest gland in the human body, and by far the most bulky of the abdominal viscera; all its functions are not yet fully understood, but it is well known that it secretes the bile, and that it transforms the grape sugar brought to it by means of the portal vein into a substance isomeric with starch (C_6 H_{10} O_5) termed *glycogen*, which in its turn is readily converted into grape sugar,—its *glycogenic function* (BERNARD).

The presence of small particles which resemble glycogen in the protoplasm of some of the lowest forms of animal life *(Protozoa)* seems to foreshadow one of the most important functions which the liver performs, although the slightest differentiation of the sarcode cannot be detected; but glycogen has also been demonstrated in most fœtal tissues, and as a constituent of amœboid protoplasm in general. The first indications of a glandular structure associated with the alimentary canal and supposed to be analogous to a liver, are to be met with amongst the *Cœlenterata* more particularly the *Anthozoa* and *Hydromedusæ*, where the projecting folds of the walls of the stomach are lined with a pigmented epithelial investment consisting of longitudinally set cells. A somewhat similar arrangement in the form of pad-like rows obtains at the basal portion of the alimentary tract in the nutritive members of the *Siphonophora*, and the large stomach of *Velella* supports a network of so-called "hepatic canals."

On passing to the *Echinodermata* it is true that glandular organs of more complex forms connected with the alimentary system occur, but their relations to that system do not seem to indicate by any means an hepatic significance; such are the *Cuvierian organs* appended to the rectum of many *Holothuriæ* composed of unbranched cæcal tubes arranged singly or in tufts *(Bohadschia)*, racemose glands *(Molpadia)*, or

filamentous lobate or tufted canals circularly disposed *(Müllerla, Pentacta)*; they secrete a sticky substance which is evacuated in the form of fine threads.

In the *Vermes* the mid-gut of *Polyzoa* and *Rotifera* exhibits a layer of pigmented coarsely granular epithelium which is supposed to represent their liver. A further development may be observed in the *Platyhelminthes* where the stomachal cæca of many Planarians and Trematodes are lined by a layer of modified epithelium. The narrowing and lengthening of the lateral appendages of the mid-gut in *Aphrodite* and the secretory function performed by their epithelial cells, is the first well-marked form of independent glandular organ associated with the mid-gut. In *Balanoglossus* the whole of the dorsal surface of the enteric canal succeeding the respiratory portion is covered with glandular appendages in the form of tubes.

Amongst the *Arthropoda* the glandular organs associated with the mid-gut form two groups. In the *Branchiopoda* mostly amongst the *Phyllopoda* the anterior portion of the mid-gut is provided with dilatations which pass into simple or branched tubes, these tubes become somewhat complicated and form a compound tubular gland placed in the cephalic shield *(Limnadia, Apus.)* The *Cirripedia* also possess similar organs. In the *Schizopoda* these cæcal tubes are simple, become very long, and pass backwards. The *Entomostraca* present simple diverticula of the enteric walls, but they are interesting inasmuch as they furnish us with an indication of a paired system which is more markedly developed in the double mass of glandular cæca, which fills a large part of the cephalothorax in all *Decapoda*; these masses are undoubtedly of an hepatic nature, and often show this in the remarkable biliary concretions, which may be found in the lobster and crayfish. Another distinct group of hepatic organs open into the posterior part of the mid-gut of many *Arthropoda*; pertaining to this, are the minute diverticula of the mid-gut of *Copepoda*, which become paired, tufted, and glandular, in some of the *Isopoda natatoria*, as in *Bopyrus squillarum*; the *Stomatopoda* moreover are peculiar in the possession of ten lobate glandular tufts placed along the mid-gut. *Epeira* and *Scorpio* and their allies amongst the *Arachnida* possess enteric cæca and tufted glands, which in structure and position accord with the anterior and posterior hepatic organs of the *Crustacea*, but the rest of the *Arthropoda (Myriapoda* and *Insecta)* are singular in the possession at the most of but rudimentary hepatic organs.

A further stage may be observed in the *Brachiopoda*; amongst the *Ecardines*, *Crania* exhibits a branched tubular organ which opens into the enlargement of the intestine by several pores; in *Lingula* this system terminates in four efferent ducts which open into the enteron. The *Testicardines* exhibit a still greater development in a pair of large lateral glands, which surround the stomach and are usually connected with it by a variable number of ducts on each side.

The Mollusca are almost all provided with well marked hepatic glands which arise primarily as sacculations of the endoderm of the middle portion of the digestive canal and its subsequent development into a more or less complicated organ. In the *Lamellibranchiata*, the liver consists

of several acini connected into large lobes adnate to the alimentary canal, they open into the stomach or succeeding part of the enteric tract. *Chiton*, as typical of the *Placophora*, shows a pair of symmetrical branched tubes communicating with the intestine. In the shelled *Gasteropoda* the liver is the largest gland in the visceral sac, it is composed of a darkly pigmented lobate mass, embracing a greater or less portion of the enteron, and connected therewith by means of a variable number of ducts which open into the mid-gut generally near the region of the stomach-like enlargement. The ducts of several of the lobes unite and widen out in the *Opisthobranchiata* to form a kind of stomachal cæcum, but the forms taken by these ducts are infinite in variety; amongst them may be noticed the numerous hepatic tubes which open into the stomach of *Doris* and *Doridopsis*, the enteric cæca of the *Æolidæ* which send blind prolongations into the dorsal cirri, when those structures are present, and are covered with glandular tissue, and the wide hepatic cæca of *Limapontia* and *Phyllirhoë*. In the *Pteropoda*, *Pneumodermon* one of the *Gymnosomata*, has a liver composed of branched groups of cæcal tubes, which open into the stomach by wide ducts giving its walls a pitted appearance. In the *Thecosomata* the enteron traverses a simpler form of gland formed of a well-defined compact mass of acini. Lastly, the *Cephalopoda* usually all possess a large and compact gland. *Nautilus* has four distinct lobes, each of which sends a duct to the mid-gut. In the *Dibranchiata* there are only two lobes, in *Sepia* these are quite separate from each other, in *Rossia* they are loosely connected; they are more firmly united in *Argonauta*, whilst in *Loligo* and *Octopus* they are joined together to form a single mass which occupies the greatest portion of the visceral cavity, and surrounds the alimentary canal; their ducts always open into the terminal portion of the cæcum.

Thus far we have observed that the liver of invertebrated animals ranges from a mere modification of the enteric epithelium chiefly distinguishable by means of its altered colour and granular texture, through dilatations of the alimentary canal, their convertion into simple and branched cæca, to the complicated glandular mass of the *Cephalopoda;* but in all these instances we find that the structure, however complex it may become, is always resolvable into a series of cæcal tubes which may branch, but do not anastomose to form a reticular system. The higher forms of the *Tunicata*, if they are to be regarded as a group of the *Invertebrata*, are remarkable for the reticularly disposed hepatic tubes which they present, and which brings that structure into close relationship with the vertebrate iver.*

Amphioxus stands alone amongst vertebrated animals in the possession of a rudimentary liver; it arises as a cæcal tube near the commencement of the alimentary canal, which passes forwards and is lined with a greenish layer of epithelium; that this is its liver is proved from the study of the development of that organ in other *Vertebrata*, where it can be made out that the epithelial layer *(endoderm)* of the rudimentary mid-gut, together with a portion of the subjacent *mesoderm* is formed

* See CHANDELON, *Rech. sur une annexe du tube dig. des Tuniciers, Bull. Acad. Belg.* XXXIX.

into a pair of cæcal diverticula lined with a greenish epithelium which is developed into a liver with reticularly anastomosing tubes, and is further provided with a special receptacle for the storage of its excess of biliary secretion—the *gall-bladder*.

Description.

We have briefly noted the most important morphological changes which have been observed in the liver, and the gradual progression which that organ undergoes, amongst the *Invertebrata*, from a simple modification of the endodermal cells of the alimentary tract in the lowest forms, to the compact tubular gland of the more highly organised groups. In passing to the *Vertebrata*, a sharp line of demarcation was supposed to exist, and the gland was said to completely alter in character and belong to an entirely different structural type; the present state of our knowledge, however, makes it obvious that such is not the case, and we are further warranted in assuming that the liver, in its most highly developed condition, is but a greatly metamorphosed compound tubular gland; and thus, instead of being isolated amongst the organs of the body, partakes of a character which places it in close relationship with all other glandular structures. We have already alluded to the reticulated structure which obtains amongst the higher Ascidians, and we have pointed out the simple tubular nature of the liver in *Amphioxus*, with its lining of greenish cells, which links it to the rudimentary liver of the *Craniota;* but whereas the liver of *Amphioxus* is a single diverticulum, that of the other vertebrates is at first paired, or, at all events, very early becomes paired (Balfour). In its future development Remak, Balfour, and others are agreed that the hepatic cells are derived from the hypoblast, and that the connective tissue and blood-vessels owe their origin to ingrowths of the mesoblast. If this be the case, and the ultimate terminations of the bile duct find expression in the minute spaces which exist between the hepatic cells, then its compound tubular nature may be taken as fairly established. Schenk,* however, maintains that the rudimentary liver of vertebrates is formed from a single mass at the lower surface of the duodenum, and that the hypoblastic cells merely give rise to the epithelial lining of the bile ducts and the gall-bladder.

The Megascopic Characters of the Liver.—The liver is invested in a *serous coat*, which, however, does not take any part in its intimate structure; it is also covered by a *fibrous coat* of connective tissue, which is in direct continuity with the delicate interlobular areolar tissue. In those parts of the liver which are closely covered by the serous coat it is less evident than where that coat is absent, as at the posterior border; and at its transverse fissure it becomes greatly thickened, and passes into the substance of the liver as a primary sheath around the portal vein, hepatic artery, and bile duct which enter thereat, and is known as the *capsule of* Glisson; this layer of tissue becomes finer and finer as the vessels which it ensheaths and accompanies become smaller.

If a portion of fresh liver be examined with a simple lens, what at first presented a coarsely granular appearance is seen to be composed of

* *Lehrbuch d. Vergleich. Embryologie d. Wirbelthiere*, Wien, 1874.

a finely granulated texture arranged in the form of polyhedral masses; these *hepatic lobules*, as they are termed, are not so well marked in the human subject as in some of the lower mammals, because the areas are produced by the interposition of connective tissue which is continuous with the outer fibrous coat and the capsule of GLISSON, and is but scanty in man, whilst in the pig and polar bear it is very markedly developed. The lobules average in diameter about 9 mm., but they vary very much in size, some being fully 12 mm., whilst others only measure 1·1 mm. in diameter. In the adult human being the lobules cannot be seen so distinctly as in the infant and in some of the lower animals, both on account of the small amount of interlobular connective tissue, and because of the colour of the cellular elements; still, even with the naked eye, the liver presents a mottled appearance, and a closer inspection shows each lobule to be composed of two differently coloured parts, one darker than the other. This led the older anatomists to suppose that there were two substances in each lobule; it is now understood that these differences are entirely due to the state of circulation of the blood within the organ; thus, if an animal be bled to death and the blood vessels of the liver thoroughly washed out with an injection of normal saline solution, the whole organ would present a uniformly pale yellowish colour; after death the hepatic veins are usually congested and the arteries empty, it then happens that the centre of each lobule is dark and its margin pale, this was termed by KIERNAN *passive congestion*. In diseases of the heart the circulation of the blood through the liver is so modified that what is known as *active congestion* of its vascular system supervenes; the blood becomes clotted in the capillaries of the hepatic and portal veins in such a manner as to darken the whole of each lobule, leaving pale intermediate spaces here and there. Sometimes in children the margins of the lobules are found dark whilst their centres remain pale, this condition is due to a congestion of the portal system. All these phenomena may be readily explained by the disposition of the blood-vascular system, which will be fully described in a future article.

THE MICROSCOPIC CHARACTERS OF THE LIVER.—Examined with a power of about 50 diameters a stained vertical section of the human liver shows its lobular character very clearly; each lobule is seen to be composed of numerous cells arranged in elongated irregular groups which extend radially from around a central space, the radii being connected at transverse intervals, and the whole presenting a retiform aspect; towards the centre of the lobule these rows of cells are tolerably regular, but they lose this character as they approach the periphery; the cells are moreover placed in single rows being doubled only occasionally. The interspaces between the lobules may also be seen to consist of vessels variously cut, and of other tissue. A power of about 250 diameters will be found sufficient to resolve all these elements satisfactorily; the central space is seen to be the transverse section of a blood-vessel *(intralobular vein)*, the cells are clearly defined, and the interlobular elements are shown to be composed of connective tissue, with blood-vessels and bile-ducts cut in different ways. In a few instances, some of these vessels are cut transversely, and from such a portion the most information can be gained respecting the structure of the

liver in the examination of a stained section. Our illustration portrays a section of this kind; the large space in the drawing *(v)* shows the relation of the *interlobular vein*, a part of the portal system, to the *hepatic cells (l)*, the *bile duct*, lined with columnar epithelium, shown cut in two places *(b)*, the *hepatic artery (a)*, and the *capillary spaces (c)*; all these structures, excepting the hepatic cells, are seen to be surrounded by a connective tissue.

The Hepatic Cells fill the interspaces between the capillaries of the blood vessels, and are supported in position by a delicate sustentacular tissue. In a simply stained section they are seen to be distinct from one another and of polyhedral shapes; as yet, the highest power of the microscope in conjunction with all the known methods of manipulation, has failed to demonstrate any cellular envelope, it is therefore stated that the cells consist of masses of protoplasm without any cell wall. They vary in diameter from 11·3 – 28·2μ, and average from 18 – 22·6μ. Each cell usually contains a single, more rarely two nuclei with nucleoli, measuring from 5·6 — 7·4μ (Frey); the surrounding protoplasm is tolerably firm, and contains numerous fine particles, giving it a granular appearance, which is attributed by recent workers to a delicate intracellular reticular structure. In an unstained fresh section the cells are seen to be of a pale brownish-yellow colour; this is largely due to the bilary pigment disseminated through their protoplasm; fatty globules may also be detected and most clearly shown by the action of dilute osmic acid which blackens them; sometimes a large quantity of fat may occur in the cells and denotes that the animal lived on a very rich diet; for this *fatty infiltration* may be induced by the administration of fatty foods, and is found in all young sucking animals. Where however the protoplasm of the cells is transformed into fat it results in a malignant disease known as *fatty degeneration of the liver*. If the cells are isolated from a newly killed animal and examined with a power of about 500 diameters on a warm stage in serous fluid or normal saline solution, they may be seen to be devoid of a cell-wall, and to exhibit slow amœboid movements (Leuckart, Schenk*).

The Connective Tissue extends over the whole surface of the liver in the form of a thin fibrous coat which becomes thicker at the posterior border, and at the *porta hepatis;* it forms a sheath, the *capsule of* Glisson which accompanies the portal vein, hepatic artery, and bile-duct to their finer ramifications.

The fibrous superficial coat and the internal ramifications of the capsule of Glisson are in direct continuity with the interlobular connective tissue, which we have pointed out occurs but sparsely in the normal human subject; when it becomes hypertrophied it constitutes the disease known as *cirrhosis*. In addition to this a very delicate sustentacular system branches off from the interlobular connective tissue; it may be demonstrated by brushing away the hepatic cells from sections which have been cut from carefully hardened pieces, or by staining sections of the fresh tissue with nitrate of silver, and brushing the hepatic cells off. If these precautions are taken, a very delicate reticulated double

* *Centralblatt f. d. Med. Wiss.*, 1869, p. 865.

membrane, with occasional small nuclei, indicating the position of connective tissue corpuscles, will be revealed, and be seen to be distinct from the network of contiguous capillary vessels, and to form a kind of lining membrane for the hepatic cells.

Methods of Preparation.

The hepatic cells, blood-vessels and lymphatics, bile-ducts, connective tissue, and nervous elements of the liver are so intricately interwoven, that an insight into their mutual relations can only be arrived at by the careful examination of sections successfully treated in a variety of ways. The characters of the hepatic cells may be observed by brushing them off sections made with a Valentin's knife from the liver of a newly killed animal; they may be mounted in glycerine, or stained with osmic acid and mounted in Farrants's solution. In the preparation of stained sections it is advisable to harden the liver, and to cut it by means of the freezing microtome.

(i.) Chromic Acid and Spirit Mixture.—(See p. 70.)—Place perfectly fresh unwashed pieces of the liver, each about half-an-inch square, in a large quantity of this solution for about twelve hours; at the end of that time a dense precipitate will have been formed by the blood and lymph which exudes from the tissue. Change the fluid, and renew it from time to time as it becomes turbid. At the end of two or three weeks they may be transferred to methylated or rectified spirit until required.

(ii.) Müller's Fluid.—(See p. 71).—Pieces about an inch square should be placed in this fluid for about eighteen hours, the solution renewed, and changed occasionally during the five or six weeks which it takes to harden the tissue; after this they may be kept in spirit.

(iii.) Potassic Bichromate Solution.—A one per cent. watery solution should be used; place half-inch pieces in this, renewing the fluid at the end of eighteen hours, for two weeks; continue the hardening for another fortnight in rectified spirit. A two per cent. solution of potassic bichromate may be used; in that case it should act on the tissues for about five weeks, being occasionally renewed during that time, and finally kept in spirit until required.

Staining in Logwood.—The best solution of logwood for staining animal tissues is that used by N. Kleinenberg, and prepared thus:—

- α. Make a saturated solution of crystallised calcic chloride in 70 per cent. alcohol, and add alum to saturation; filter.
- β. Make a saturated solution of alum in 70 per cent. alcohol.
- γ. Add one part of α to eight of β.
- δ. Make a barely alkaline saturated solution of hæmatoxylin in distilled water.

To stain the sections, place them in a small bottle or watch-glass containing a mixture of one ounce of γ and ten or twelve drops of δ, until they are sufficiently coloured, then wash in plain water, and mount in glycerine, glycerine jelly or Farrants's solution. For mounting in Canada

balsam, or dammar solution, the sections should be overstained and the excess of colour removed by steeping them in spirit, when they may be removed to oil of cloves, and mounted in the usual way (See pp. 6, 15).

An excellent logwood stain is prepared by W. MARTINDALE, 10, New Cavendish Street, Portland Place, London, W. Three drops of this dye added to an ounce of distilled water, should be allowed to act upon the sections for about quarter of an hour, or until they are well stained; diffuse colouring may be removed by the use of a very dilute solution of acetic acid. The slices may then be transferred to methylated or rectified spirit for a few minutes, cleared in oil of cloves, and mounted in Canada balsam or dammar solution.

LIVER OF CAT.

V. S. Injected.

Hepatic Vein, Red; Portal Vein, Blue.

× 50 diameters.

Etymology.—CĂT, *n.* [A-S. *cat*, D. and Dan. *kat*, Sw. *katt*, Icel. *köttr*, L. Ger. *katte*, H. Ger. *katze*, *kater*, O. Fr. and Pr. *cat*, N. Fr. *chat*, Catalan *gat*, Sp. and Pg. *gato*, It. *gatto*, Ir. *cat*, W. *câth*, Corn. *kath*, Armor. *kaz*, *kâch*, Late Lat. *catus*, Bisc. *catua*, N. Gr. γάτα, γάτος, Russ. and Pol. *kot*, Turk. *kedi*, Ar. *qitt*]. *(Zoology).* A species of carnivorous animal belonging to the genus *Felis*. *Felis domestica*, the domestic cat, is supposed to be derived from the wild cat *(Felis catus)*.

LĬV'ER, see p. 79, for etymology, etc.

DESCRIPTION.

In the accompanying plate, a single lobule of the liver of the cat has been depicted, with the view of showing the relations of the hepatic venous and portal blood-vascular system therein. The hepatic vein has been injected with a red and the portal with a blue mass, by a method to be afterwards described. In the centre of the lobule, which has been specially chosen because it happens to have been symmetrically cut and well injected, the transverse section of the hepatic *intralobular* vein is shown, from which a capillary network is seen to radiate, and to join a system of other *interlobular* capillaries which terminate in variously cut twigs of the portal vein at the periphery of the lobule. The clear spaces left by the capillary meshwork indicate the position of the hepatic cells, and the picture is thus a counter part of what has already been considered at page 83, etc.

THE BLOOD-VASCULAR SYSTEM of the liver is peculiar in that it is derived from two distinct sources,—from the *hepatic artery* and the *portal vein*. The hepatic artery is a branch of the *cœliac axis* and is small when compared with the large organ to which it is distributed; the portal vein on the other hand is a large vessel formed by the union of the *gastro-splenic*, *pancreatic*, *intestinal*, and *omental veins;* it lies in company with the hepatic artery and bile-duct in the fold of the gastro-hepatic omentum above the foramen of WINSLOW and thus reaches the transverse fissure of the liver to enter into and ramify through its substance; at that fissure the hepatic artery lies to the left hand side, the bile-duct to the right, and the portal vein behind them. Numerous lymphatics and nerves accompany them, and they are invested by the sheath of connective tissue known as GLISSON'S capsule. The blood is

conveyed away from the liver by the *hepatic veins* which take an entirely different course from the other vessels; they pass out of the organ at its posterior border where they end in three principal branches and terminate finally in the *Vena cava inferior*. It is evident from what has already been stated that the system of capillaries formed by the hepatic artery and portal vein, must ultimately form a union to permit of the flow of their blood into the hepatic vein and thus into the general venous system of the body.

The course of the hepatic artery through the liver points to its physiological significance more as a nutrient vessel to the hepatic tissues than as an accessory to the production of bile; its branches are accompanied by those of the portal vein and bile-duct, to the coats of which, as well as to the adjacent connective tissue, it supplies nutrient vessels known as *rami vasculares*. It also sends branches to the fibrous covering of the liver *(rami capsulares)* where it forms a wide-meshed capillary system, the veins of which terminate in the portal system. A third set of branches *(rami lobulares)* pass into the lobules of the organ where their terminal capillaries are very peculiarly arranged; and to this portion may be ascribed a participation of the hepatic artery in the biliary function of the liver; the *rami lobulares* pass into the peripheric portions of the lobules, and their capillaries join the capillary network of the lobule intermediately between those of the hepatic vein and portal system. Thus, if it were possible to make a perfect injection of the hepatic artery with a colour different from those used in the injection of the hepatic vein and portal vein, its capillary system in the lobules would be seen to join the other capillaries at the junction of the blue and red in the illustration.

The *portal vein* from its course through the liver suggests its function as pre-eminently the elaborator of bile; it passes into the organ alongside the hepatic artery and bile-duct to terminate in numerous branches situated between the lobules—the *venæ interlobulares* (KIERNAN*) or *venæ perifericæ* (GERLACH†) A slight difference obtains in different animals in the precise arrangement of these interlobular twigs of the portal vein; in the human being and cat they form short loops surrounding the lobules, in the rabbit these loops are very much longer, whilst in the pig they take on the character of regular rings. From these interlobular vessels a most complicated set of capillaries arises either directly from the interlobular twigs, or from finer branches which they give off; these capillaries open on the one hand into those of the rami lobulares of the hepatic artery, and on the other into the system connected with the hepatic vein. The capillary vessels according to FREY‡ measure from 9μ to 12·6μ in diameter, and the meshes of the dense network in the human subject vary from 22·6μ to 45·1μ; these meshes are either circular, oval, squarish, triangular, or irregular in contour, and generally have their long axis verging towards the central point of the lobule.

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* *Philosophical Transactions of the Royal Society*, London, 1833.

† *Handbuch der allgemeinen und speciellen Gewebelehre*, Mainz, 1848, S. 280, *et seq.*

‡ *The Histology and Histochemistry of Man*, translated by A. E. J BARKER, London, 1874, p. 504.

The *hepatic vein* is formed by a convergence of the dense capillary network, in which the hepatic artery and portal vein terminate at the periphery of each lobule, which joining to form fine blood-vessels enter a central lobular system. To this system KIERNAN* has applied the term *venæ intralobulares*, and GERLACH† has called them *venæ centrales*. These intralobular central veins open into larger vessels, the *sublobular veins*, upon which the lobules thus come to rest. If one of these sublobular veins be opened its thin walls permit the polygonal areas marked out by the lobules to be viewed with great distinctness; in such a dissection the centre of each lobule may be seen to be pierced by a dark spot—the opening of an intralobular vein. The walls of the capillaries are so very delicate that they can only be detected with great difficulty. If a very thin section of a carefully hardened liver be brushed gently with a fine soft hair pencil so as to remove the hepatic cells, a delicate network of tissue will be revealed; this tissue, as has already been stated‡, consists of the sustentacular tissue of the liver, together with the capillary network; the latter is revealed by the presence of the nuclei of their cells, and may be best demonstrated in the liver of young animals; in the adult condition these appearances are not so well marked; the connective tissue and capillary walls are apparently fused together, although in reality they remain distinct from one another (BEALE**).

The BILE-DUCTS.—The biliary system of the liver terminates in a duct, the *hepatic duct*, which, uniting with the *cystic duct* from the gall-bladder, forms a *common bile duct* which opens finally into the duodenum. According to HENLE, the walls of the gall-bladder are formed of layers of connective-tissue and non-striated muscular fibres alternately disposed; the muscular fibres decussating in all directions; the mucous membrane is arranged in regular folds, and is lined by a layer of columnar epithelial cells. From the cystic duct numerous follicles are given off which are indefinitely disposed or may obtain in rows; these mucin forming glands are of commonest occurrence at the inferior portion of the cystic duct, in the hepatic duct, and common bile duct; they are more sparingly found in the gall-bladder, and may be traced as far as some of the larger interlobular ducts within the liver. By some observers they are looked upon as simple diverticula of the biliary system, and not as special glandular structures. It is comparatively easy to trace the course of the hepatic duct within the liver, when that system has been successfully injected; its ramifications may be traced alongside the branches of the portal vein to an interlobular system from which a network of thin-walled biliary vessels take their rise; beyond this it becomes a matter of extreme difficulty to trace them to their ultimate terminations. In well stained uninjected sections, the walls of these interlobular bile-ducts may be seen to consist of a fine fibrous coat of connective tissue bearing a layer of columnar cells; with a high power of the microscope these cells exhibit a clear striated border, and well-defined oval nuclei. In the larger ducts a distinct mucous membrane may be observed, and it has been stated that a layer of unstriped muscular fibres also exists in their walls.

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* Loc. cit.
† Loc. cit.
‡ See Ante. pp. 84, 85.
** *Phil. Trans., Roy. Soc.*, London, 1856.

From the interlobular bile-ducts a very delicate network of tubes may be traced between and around the hepatic cells. The true characters of these *bile-capillaries*, and their relations to the blood-vascular and cellular elements of the liver, have given rise to the most varied opinions amongst histologists. The results of their investigations may, however, be briefly summarised in what is now generally accepted. The meshwork of bile-capillaries pass between the hepatic cells so as to come into close contact with their faces at various parts; the vessels are extremely fine, they have been measured in the rabbit by FREY*, who assigns to them a diameter of from 1·8 — 2·5μ. The meshes take on a somewhat cubical arrangement corresponding on an average with the size of the hepatic cells, and being slightly smaller than those of the blood-capillaries; in the rabbit the breadth of the meshes varies from 14·4 — 20·1μ.

The bile-capillaries do not come into direct contact with the blood-capillaries; there is always a small portion of hepatic matter between them, so that the secreting cell is placed in an intermediate position (ANDRÉJEVIC**). MAC GILLAVRY†, however, supposes that they are interlaced in such an intricate manner that the biliary radicles do sometimes lie against the blood-vessels. A consideration of the structure of the liver in the lower vertebrates shows that ANDRÉJEVIC'S view is probably the correct one, for HERING‡ and EBERTH§ have pointed out that in the lower animals one or two rows of hepatic cells may intervene, and that in the higher vertebrates there always is a whole or a portion of an hepatic cell between the biliary capillary and the blood-vessel. In sections of hardened liver the bile-capillaries may be seen to originate between the hepatic cells in the form of minute spaces. By some these are regarded as forming a lacunar network, but there is no doubt that the biliary ducts in their ultimate distribution, do possess walls as first noted by MAC GILLAVRY, and subsequently confirmed by EBERTH. CHRZONSZCZEWSKY‖ also, by his method of natural injection, has clearly demonstrated the existence of a delicate envelope around the bile-capillaries, and the general relations of the biliary system to the hepatic cells and blood-vessels.

THE LYMPHATIC SYSTEM of the liver is manifested in form of a superficial and a deep set of vessels. The *superficial lymphatics* lie in the deepest layer of the peritoneal investment of the organ, and consist of a network of fine canals from which large efferent vessels pass off in all directions; those on the upper surface communicate with the thoracic glands after passing through the ligaments of the liver. The subperitoneal plexus, which is in direct continuity with the deeper lymphatics which emerge at the portal fissure, opens into the lymph nodes at that fissure, and near the gall-bladder. The *deep lymphatics* enter the organ along with the hepatic arteries, portal veins, and bile-ducts, and with them are enveloped in the fibrous sheath of GLISSON'S capsule. They surround their accompanying vessels with a delicate network, and continue as distinct vessels until they reach the interlobular regions; thereafter they may preserve

* *Handbuch der Histologie und Histochemie des Menschen*, Leipzig, 1876.
** *Sitz. d. k. Akad.*, Wien, 1861, Bd. xliii, Abth. i, S. 379.
† *Sitz. d. k. Akad.*, Wien, 1865, Bd. i, Abth. ii, S. 207.
‡ *Sitz. d. k. Akad.*, Wien, 1866, Bd. liv, Abth. i, S. 335.
§ *Virchow's Archiv*, Berlin, Mai, 1867, Bd. xxxix, S. 70.
‖ *Virchow's Archiv*, Berlin, Jan., 1866, Bd. xxxv, S. 153.

their vascular character to a limited extent, but obtain chiefly in form of perivascular channels which invest the blood-capillary system of the lobules (Mac Gillavry*), and whose external boundaries are determined by the delicate sustentacular tissue which supports the bands of hepatic cells (Frey†). In the liver of the pig, Kisselew and Chrzonszczewsky have moreover succeeded in demonstrating a number of lymphiod follicles in connection with the interlobular lymphatic system.

The Nerves of the liver are derived from the *plexus cœliacus*, and from the *vagi*, more particularly from the left vagus. They enter the substance of the liver, chiefly associated with the hepatic artery, at the transverse fissure of that viscus, and are distributed throughout the organ to its blood-vessels and bile-ducts. The ultimate terminations of the nerves have not yet been satisfactorily determined, and their entire physiological action is still an enigma. It is true that Pflüger‡ has stated that he has traced nerve fibrils into the substance of the hepatic cells, where he supposes that they terminate; but although this is highly probable, it has not yet received any support from the confirmatory evidence of competent observers.

Methods of Preparation.

Chrzonszczewsky's Method of Natural Injection.—By a series of carefully conducted experiments on living animals, Chrzonszczewsky was enabled to contribute very largely to our knowledge of the anatomy and physiology of the liver. He succeeded in injecting the bile-ducts throughout their course in the lobules, by introducing a solution of sulphindigotate of soda in repeated doses into the circulation of dogs and sucking-pigs through the jugular vein, and killing the animals after an hour and a half had elapsed. He then washed out the blood-vessels of the liver by means of a solution of chloride of potassium injected through the portal vein, or filled them with a gelatine and carmine mass. On cutting sections of the liver, the bile-ducts were found to be perfectly injected with a blue colour, and the blood-vessels filled with red; the method when successfully carried out enabled him to verify Andréjevic's statement that the bile-capillaries are separated from the blood-capillaries by a variable amount of hepatic matter, and that the bile-capillaries are bounded by a delicate wall, and do not exist as mere intercellular passages, thereby adding weight to the conclusions of Mac Gillavry. By killing the animals sooner, he found the blue pigment partially within the hepatic cells, and thus proved directly that the cells are the active agents of secretion within the organ, and that they extract matters from the blood-vascular system and transmit them to the hepatic system. By a modification of these experiments, he elucidated the quantitative value of the separate systems of circulation, and showed exactly what share is taken by the hepatic artery and portal vein in the cholapoietic function of the liver; thus by tying the portal vein he found that the biliary system at the peripheral portions of the lobule was coloured, whilst the centres of the lobules remained colourless, and by tying the hepatic artery

* *Loc. cit.*

† *Handb. d. Histol. u. Histoch. d. Mens.*, 5th ed. Leipzig, 1876.

‡ *Archiv für Physiologie*, Bd. iv, p. 58.

he induced an exactly opposite result. From these experiments, he also deduced a most important physiological fact; he showed that the circulation of the blood within the liver must take place very slowly, for when the portal vein was ligatured, *all* the blue colouring matter was deposited in the peripheral bile-ducts of the lobules, thus proving the tardy character of the movement of the blood, which had it been otherwise would certainly have carried the pigment towards the centre of each lobule.

METHOD OF INJECTING THE PORTAL VEIN AND HEPATIC VEIN.—The freshly killed animal ought to be bled, and its vascular system washed out with a ¾ per cent. solution of sodium chloride. The liver should then be injected *in situ* through the portal vein with a blue, and the hepatic vein with a carmine, gelatine mass; the amount of the injection to be used must be judged by the external appearance of the lobules. The organ should then be detached, hardened in a two per cent. solution of potassic bichromate, or in alcohol, the sections cut, and mounted in Canada balsam.

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THE KIDNEY.

ETYMOLOGY.—KID'NEY, *n.*; *pl.* KID'NEYS. [Probably from A—S. *quidh*, *cwidh*, Icel. *qvidr*, O. H. Ger. *quiti*, Goth. *qvithus*, belly, womb, Eng. *nigh*, and Lat. *renes*, Gr. νεφροί, the kidneys]. *(Anatomy)*,—Differentiated excretory organs which probably perform a renal function, or at all events are concerned in the elimination of the nitrogenous products of waste from the animal economy first make their appearance in the *Vermes*, in the form of a *water-vascular system* in some, and of *segmental organs* in others. Although no structure is discernible in the lower forms of life *(Protozoa)* to which a renal function may be assigned, still it is not improbable that that office is in part performed by the so-called contractile vacuoles which obtain in many of them.

In the *Echinodermata* excretory organs have not been satisfactorily made out; in the *Holothuridea* canals have been observed in the body wall beset with infundibular organs, which open into the cœlom; ciliated organs have also been made out in connection with the dorsal canal of the arms of *Crinoidea*, and to these a renal function has by analogy been ascribed, as well as to the water-vascular system, inasmuch as it approaches in some respects (e. g. its communication with the exterior on the one hand, and with the blood-vascular system or what is practically the same thing, the cœlom, on the other hand) to the form of excretory apparatus in the *Mollusca*.

The organ of excretion obtains in three characteristic forms amongst the *Arthropoda*. The *green-gland* of the Lobster and Crayfish is regarded as a renal organ; it is lodged in the front part of the head of the animal, below the anterior aspect of the cardiac portion of the stomach, in a sac which opens by an excretory duct, the orifice of which is placed in the centre of a papilla situated on the basal joint of each antenna; the presence in this organ of guanin* adds weight to the statement that it is a renal organ. No such organ can be found in any of the adult *Entomostraca*, but they have been demonstrated in nearly all their larval forms. In the *Cirrepedia* they have probably become modified to subserve the requirements of their mode of life in the so-called *cement glands*. Another form of organ supposed to be renal, occurs amongst the lower *Crustacea*; it consists of a transparent looped arrangement situated in the pallial-like fold of the dorsal integument, and is known as the *shell-gland (Entomostraca)*. The third variety obtains amongst the *Tracheata* as diverticula of the hind-gut of the enteric canal; they occur in form of long canals which may be simple or branched, and are often disposed in numerous coils around the alimentary canal; they have long been known as the *Malpighian vessels* or *urinary canals (Insecta, etc.)*

* WILL UND GORUP-BESANEZ, *Gelehrte Anzeigen d. k. Baienzschen Akademie*, 1848, No. 233.

The *Brachiopoda* resemble the *Annelida*, amongst the *Vermes*, in the possession of excretory organs which take on the character of looped canals (segmental organs); they open externally near the base of the arms, and taking a bent course communicate by funnel-shaped orifices with the cœlom.

On passing to the *Mollusca*, the excretory organs are found to be well marked and essentially homologous with the renal organs of some of the *Vermes*. In the *Lamellibranchiata* they form a paired-gland termed the *organ of* Bojanus, which lies on the dorsal aspect of the body in the middle line close to the base of the branchiæ; it consists of a dark brownish or yellowish tissue, which encloses a lacunar system terminating in a large central space, and it communicates directly on the one hand with the exterior, and on the other with the blood-vascular system; the generative organs, moreover, are closely associated with it. The renal organ of the *Gasteropoda* becomes unilateral through the degeneration of one side of an originally paired system; as in the other *Mollusca*, it communicates by one pore with the pericardial sinus, and by another with the exterior. In the *Pteropoda* the similarity in the disposition of its orifices have marked out an organ of a very spongy texture (which in some instances is also a contractile organ) as the *kidney;* although it has not been shown as in the Lamellibranchs and Gasteropods that concretions of a urinary character occur here. In the *Cephalopoda* the *vena cava* divides into as many afferent vessels as there are gills; each of these branches traverses a chamber which is in direct communication with the mantle cavity, and the wall of the blood-vessel which thus comes into contact with the water at this part is greatly sacculated, and forms a glandular organ which thus comes to lie in this *renal chamber*. Amongst the products of excretion, it may be noted that *uric acid* has as yet been only detected amongst Gasteropods and Cephalopods.

"The higher *Vertebrata* are all provided with two sets of renal organs, the one existing only during the early fœtal state, the other persisting throughout life."

"The former are the *Wolffian bodies*, the latter the true *Kidneys*."

"The Wolffian bodies make their appearance very early, on each side of the ventral aspect of the spinal region of the embryo, as small transversely-disposed tubuli, opening into a duct which lies upon their outer side, and enters, posteriorly, into the base of the allantois, and thence into the primitive cloaca with which that structure is connected. The Wolffian duct is one of the first-formed structures in the embryo, and precedes the tubuli."

"The *Kidneys* appear behind the Wolffian bodies, and, apparently, independently of them; their ducts, the *ureters*, are also distinct, but likewise terminate in the pelvic part of the allantois. Thus the urinary secretion passes into the allantois, and it is that portion of this organ which lies within the abdomen, and becomes shut off from the rest by the constriction and obliteration of the cavity of an intermediate part, and its conversion into the *urachus*, that gives rise to the *urinary bladder*. The ultimate secreting tubuli of both the Wolffian body and the kidney, are alike remarkable for ending in dilatations which embrace convoluted capillaries,—the so-called *Malpighian* tufts. Neither Wolffian bodies nor kidneys have been observed in *Amphioxus*. It is doubtful whether

true kidneys are developed in *Ichthyopsida*, or whether the so-called kidneys of these animals are not, rather, persistent Wolffian bodies." (HUXLEY*).

EXPLANATION OF PLATE.

DIAGRAMS OF THE KIDNEY.

FIG. I.—L. S. THROUGH THE PELVIS AND SUBSTANCE OF THE RIGHT HUMAN KIDNEY. (*After* QUAIN.) "½ natural size. *a*, the cortical substance; *b,b*, broad part of two of the pyramids of MALPIGHI; *c,c*, calices or infundibula of the pelvis laid open; *c'*, calyx unopened; *d,d*, summit of the pyramids or papillæ projecting into the calices; *e,e*, section of the narrow part of two pyramids near the calices; *p*, pelvis or enlarged portion of the ureter within the kidney; *s*, the sinus; *h*, the hilus; *u*, the ureter."

FIG. II.—DIAGRAM SHOWING THE COURSE OF THE RENAL TUBULES AND THEIR VARIATIONS IN THE DIFFERENT SECTIONS OF THE CORTEX AND MEDULLA. (*After* KLEIN, *Atlas of Histology*, p. 264). "A, cortex limited on its free surface by the capsule; *a* subcapsular layer not containing Malpighian corpuscles; *a'*, inner stratum of cortex without Malpighian corpuscles; B, boundary layer; C, papillary part next the boundary layer; 1, Bowman's capsule of the Malpighian corpuscle; 2, its neck; 3, proximal convoluted tubule; 4, spiral tubule of SCHACHOWA; 5, descending limb of Henle's loop; 6, the loop proper; 7, thick part of the ascendir g limb; 8, spiral part of the same; 9, the narrow ascending limb in the medullary ray; 10, the irregular tubule; 11, the intercalated section of SCHWEIGGER-SEIDEL, or the distal convoluted tubule; 12, the curved collecting tubule; 13, the straight collecting tubule of the medullary ray; 14, the collecting tube of the boundary layer; 15, the large collecting tube of the papillary part; in the papilla itself, not represented here, this tube becomes confluent with others and thus forms 16, the duct."

FIG. III.—DIAGRAMMATIC DRAWING OF MALPIGHIAN CORPUSCLE. (*After* KLEIN, Fig. 149, *Handbook for the Phys. Lab.*, × 350 diameters). "*a*, glomerulus; *c*, epithelium covering the glomerulus; *d*, flattened epithelium lining Bowman's capsule; *f*, urinary tubules in section.

FIG. IV.—DIAGRAM OF BLOOD-VESSELS. (*After* LUDWIG from *Klein's Atlas of Histology.*) "*a i*, interlobular artery; *v i*, interlobular vein; *g*, glomerulus of Malpighian corpuscle; *v s*, vena stellata; *a r*, arteria recta; *v r*, vena recta; *a b*, bundle of arteriolæ rectæ; *v b*, bundle of venæ rectæ; *v p*, network of vessels around the mouth of ducts.

FIG. V.—INJECTED GLOMERULUS FROM THE INNER PART OF THE CORTICAL SUBSTANCE OF THE KIDNEY OF A HORSE, × 70 diameters. (*After* BOWMAN, *Phil. Trans.*, 1842). "*a*, interlobular artery; *a f*, efferent artery; *m,m*, convoluted vessels of the glomerulus; *e f*, efferent or straight arteriole; *b*, its subdivision in the medullary substance.

DESCRIPTION.

THE MEGASCOPIC CHARACTERS OF THE HUMAN KIDNEY.—In external shape the human kidney is so characteristically developed that the term reniform which has been named from it is constantly employed in ordinary language to denote a form which is kidney-like, and resembles a bean in its general outlines. The organ is closely invested by a thin strong fibrous coat, the *tunica propria*, which is loosely attached to its substance by a very delicate areolar tissue and minute blood-vessels; on reaching the *notch* or *hilus* (*h.* Fig. I.) the tissue of this coat becomes continuous with the external surface of the infundibulum formed by the dilated portion of the emergent *ureter (u.)*, and the adherent nutrient blood-vessels, etc., which enter at this part. A longitudinal section such as that represented by Fig. I., when looked at without the aid of a mag-

* *Anatomy of Vertebrated Animals*, London, 1871, pp. 94, 95.

nifier, shows an external hollowed portion which dips down around the infundibulum from the hilus, and is termed the *sinus (s.)* The emergent ureter is greatly dilated, just before it leaves the organ, by the confluence of its primary sub-divisions, and the chamber thus formed is termed the *pelvis (p.)* From the pelvis prolongations of the ureter are seen to pass into the substance of the organ, and to terminate abruptly in cup-like depressions the *calices (c.)*; into these calices little conical protrusions depend *(d.)*, and are the summits of pyramidal structures,—the Malpighian pyramids, which lie apposed to one another, and together constitute the substance of the organ. If the ends of these pyramids which thus project into the calices be carefully examined, they will be seen to be perforated by numerous orifices,—the openings of the uriniferous tubules. An ordinary lens reveals, further, that the interspaces between the pyramids are occupied by septa of tissue to which the name *columnæ Bertini* has been applied. The substance of the kidney is further roughly divisible into two portions, an inner pale *medullary*, and an outer reddish-brown *cortical* layer. The difference in appearance of these layers is traceable to a difference in the disposition of the various parts which build up the structure, and which can only be fully considered under the microscope.

THE KIDNEY.

H. S. Through Medullary Layer.

Stained Logwood.

× 400 diameters.

l. Large collecting tube, *s.* Smaller collecting tube,
h. Tube of Henle's loop, *c.* Capillary blood-vessel,
v. Venous capillary.

Etymology.—KID'NEY, *n.*; *pl.* KID'NEYS. See p. 109.

DESCRIPTION.

THE MICROSCOPIC CHARACTERS OF THE HUMAN KIDNEY.—In intimate structure the human kidney consists essentially of a complex arrangement of tubules, the *tubuli uriniferi*, whose functions depend upon their characteristic association with the blood-vascular system, the whole being invested and supported by a sustentacular framework of connective tissue, and supplied with lymphatics and nerves.

THE CONNECTIVE TISSUE which forms the framework may, from the manner in which it is disposed in the various parts of the organ, be considered under the three following heads :—

1°. The *outer capsule* which envelopes the kidney consists of a layer of connective tissue, chiefly of the white-fibrous variety amongst which flattened connective tissue corpuscles may be detected with a high power by their deeply stained nuclei. Towards the periphery the tissue is very compactly arranged, but its deeper portion becomes slightly areolar, and the tenuity of its fibres increases as they dip down to become continuous with the intertubular tissue of the underlying cortex. It may be noted that in this downward course they pass chiefly together with the blood-vessels which run between the cortex and the capsule, and become mixed with a number of delicate elongated cells which EBERTH has described as a plexus of non-striated muscular fibres.

2°. The phrase *connective tissue of the parenchyma* may be taken as inclusive of the intertubular and the perivascular elements; and these vary in different parts of the organ. A delicate fibrous tissue spreads around the tubules of the cortex filling up the interspaces between them, and every here and there exhibiting a corpuscle whose well-marked oval nucleus defines its position (See Fig. III, p. 111). Its continuity with the capsular tissue has already been pointed out. In the region of the Malpighian corpuscles the connective tissue, with its corresponding corpuscles, becomes excessively delicate, and according to LUDWIG and

ZAWARYKIN* is always present to a greater or less extent; it becomes continuous with the tissue which surrounds the afferent arterioles, and thus with that of the interlobular arteries and the larger vessels of the medullary substance of which they are branches. From these the tissue may be traced around the arteriolæ rectæ into the boundary layer between the medulla and the cortex, where it becomes very scanty and assumes a hyaline honey-combed membranous aspect (KLEIN†), as the sustentacular substance of the tubules and capillary blood-vessels. The connective-tissue corpuscles in this position may be branched or spindle-shaped, and possess oval nuclei which are usually disposed transversely to the long axis of the tubules (SCHWEIGGER-SEIDEL‡). On reaching the papillary portion of the medulla, the connective tissue increases in quantity, and is more markedly fibrous; especially towards the apices where it merges into the superficial layer which invests the papillæ. Besides all this, the blood-vessels on their entry into the substance of the organ are accompanied by bands of longitudinally disposed muscular fibres, associated with an appreciable quantity of connective tissue, which takes its origin in the subjacent submucous tissue which will presently be noted, and which persists around those vessels until it is lost in the homogeneous tissue of the boundary layer.

3°. The free surface of the pelvis and calices (Fig. I, p. 111, *p. c.*), is, like the inner surface of the ureter, lined by a layer of stratified transitional epithelium which rests upon a membranous expansion formed of a dense meshwork of white-fibrous connective tissue and its corpuscles; this *mucous coat* passes by gradual transitions into a loosely arranged *submucous layer*, in which, at its inner aspect, longitudinal and circular layers of non-striated muscular fibres place it in continuity with the muscular coat of the ureter, and which obtain only as circular bands on the papillæ (HENLE‖). Its outer more deeply seated portion bears a small quantity of adipose tissue; and a few elastic fibres may be detected in various situations throughout its extent.

THE PARENCHYMA OF THE KIDNEY consists of the *tubuli uriniferi*, which, in association with the blood-vessels, gives rise to the characteristic appearance of the substance of the organ. If a section such as that depicted in Fig. I, p. 111, be examined, two tolerably distinct regions may be recognised:—an inner part termed the *medullary*, and an outer the *cortical layer*. Of these, the former is further divisible into a *papillary portion*, and the *boundary layer*.

In most mammals the medullary layer is constituted by numerous converging lines terminating in a single conoid papilla, the apex of which is directed towards the hilus. In man, and in the pig, from 10 to 15 of these *pyramids of* MALPIGHI depend into the pelvis.

The papillary portion of each pyramid is uniformly marked by numerous vertical striæ, due to the straight course which the urinary tubules and blood-vessels take in passing to the apex of the papilla. The boundary

* *Sitz. d. k. Acad.*, Wien, Bd. xlviii, 1864.
† *Atlas of Histology*, London, 1880, p. 252.
‡ *Die Nieren des Menschen und der Saügethiere*, Halle, 1865.
‖ *Zur Anatomie der Nieren, Abhandl. d.k. Gesell. d. Wiss.*, Göttingen, 1862, Bd. x.

layer is somewhat similarly striated, and its markings are found to be due to the same causes, the urinary tubules and the blood-vessels taking a parallel vertical course through it; but whereas they are indiscriminately disposed in the papillary portion, they are grouped into separate alternating columns which bestow a banded appearance to this portion; the associated tubules forming opaque, and the blood-vessels *(vasa recta)* light bands.

The opaque columns of the boundary layer, constituted by the uriniferous tubules, continue their course towards the peripheric capsule of the kidney. In doing so they form portions of the cortical layer termed *medullary rays*, which diminish gradually in width as they approach the capsule, and terminate altogether at a short distance from that part; thus assuming the form of slender cones, known as the *pyramids* of FERREIN. Interposed between the medullary rays are areas characterised by a *labyrinth* of convoluted tubules, which mark out the limitary region of the *Malpighian corpuscles;* and in this region the most external, and the most internal layers of the cortex respectively, form zones which are devoid of Malpighian corpuscles. In summing up the relative value of these parts in a vertical section, KLEIN* gives the following estimations:—"Taking the vertical diameter of both the cortex and medulla together as 10, the relative proportions of the above three sections, viz., cortex, boundary layer, and papillary portion are about 3·5 : 2·5 : 4." and "Taking the vertical diameter of the cortex as 7, we find a layer of the thickness of 1 next the capsule, and one of 0·8 next the boundary layer, without any Malpighian corpuscles," as shown in the diagram, p. 111, Fig. II, as *a* and *á*.

The urinary tubules commence in dilatations which embrace tufts of blood-capillaries and thereby constitute the *Malpighian corpuscles;* they thereafter take a complicated but definite course through the organ to terminate in openings on the free surface of the papillæ. In this course each tubule not only varies in situation, but with its change of shape and position, acquires differences in intimate structure, which admits of its division into several distinct portions. The diagram Fig. II, p. 111, maps out the course and relations of the renal tubules with great clearness; it is there shown that each tubule from its commencement in the Malpighian corpuscle to its termination in one of the ducts which open on the papilla, is divisible into sixteen distinct sections, which differ from one another so markedly, that they require to be individually considered.

1. The *Malpighian corpuscle* (p. 111, Fig. II, 1; Fig. III). In the early development of the embryo, the terminal portion of the uriniferous tubule becomes invaginated by the progressive growth of the *glomerulus*, which consists of a a tuft of blood-capillaries. It thus happens that the membranes which enter into the structure of the renal tubule are reflected over the Malpighian tuft, which, increasing in relative size, at length gives rise to the characteristic bulbous form. When fully developed, the body thus formed consists of an outer homogeneous spherical capsule, which is an expansion of the distal free extremity of the renal tubule; its periphery is tucked in, in form of a fine sac which projects into,

* *Atlas of Histology*, London, 1880, p. 253.

and nearly fills its entire cavity. Into this sac depends the glomerulus. The *capsule of* BOWMAN thus constituted out of a hyaline *membrana propria*, is thickened externally by a greater or less proportion of a delicate fibrous tissue (LUDWIG), which, as may be expected, dips in to form an investment for the glomerulus. The inner surface of Bowman's capsule is lined by a layer of epithelial cells; in their early stages these cells are somewhat polyhedral in form; as age advances, those which line the external capsule become flattened, whilst those which cover the reflection over the glomerulus remain polygonal (see p. 111, Fig. III, *c*, *d*); but in the course of time these also become flattened. They all possess well marked flattened oval nuclei, and may be distinctly revealed by injecting a solution of silver nitrate through the blood-vessels, and treating them by a method to be hereafter described.

The *glomerulus* (p. 111, Fig. II, 1; Fig. III, *a;* Fig. V, *m*,*m*), enveloped in the invaginated capsule of the Malpighian corpuscle, takes its origin in a small afferent arteriole which branches off an interlobular artery, and enters the capsule at its inverted extremity, i.e., opposite to the neck of the tubule (p. 111, Fig. II, 2). Within this chamber it breaks up into a network of convoluted capillary blood-vessels, which are further arranged into two or more ovoid lobules, whence an emergent or efferent arteriole leaves the glomerulus by the side of the afferent vessel, and with it forms a kind of peduncle to the tuft. The lobules of the glomerulus are invested in a delicate connective tissue, continuous with a homogeneous substance which binds them together. According to AXEL KEY* this connective tissue contains somewhat flattened, branched, and nucleated corpuscles. The whole tuft is moreover enveloped in a delicate membrane composed of a single layer of nucleated endothelial plates, which dips in between the lobules HEIDENHAIN.† Between the glomerulus and the capsule of Bowman there is always an empty space, the extent of which varies with the physiological activity of the organ, and is therefore to a very large extent dependent upon the normal or abnormal state of excretion.

2°. *The neck of the Malpighian corpuscle* (p. 111, Fig. II, 2), is the constricted channel which places the space around the glomerulus in communication with the lumen of the tubule. The epithelial lining of Bowman's capsule becomes so attenuated in this section that it appears to be devoid of any lining membrane, and to consist merely of a membrana propria thickened on the outer side by connective tissue.

3°. *The Proximal Convoluted tubule* (p. 111, Fig. II, 3) commences as a dilatation of the neck, and increasing slightly thereafter in diameter, takes a tortuous course of considerable length within the labyrinth of the cortex to which it is confined. Its membrana propria is a continuation of that of the neck, and therefore of Bowman's capsule; but its lumen is reduced to about one third of its whole diameter on account of the single layer of epithelial cells which line its walls. The membrana propria and epithelial lining possess certain details of structure, which are com-

**Om Circulationsförhållandena i Njuarne*, Stockholm, 1865.
†*Arch. für Mikr. Anat.*, Bd. x, 1874.

mon to other parts of the renal tubules, and will therefore be considered fully in this section.

Throughout the cortical and medullary layers, the membrana propria retains a uniform aspect; at some places obscure lines, and the presence of an angular nucleus which passes towards the internal epithelium, lead us to surmise that it consisted primarily of a series of endothelial plates which have become fused together; and this conclusion is supported by analogous phenomena, which have been demonstrated in the tubes of other glands.

The epithelial cells which line the membrana propria of this section and all the other parts of the tubule with the exception of 5, 6, 12, 13, 14, 15, and 16, Fig. II, p. 111, are peculiar in the arrangement of their protoplasmic substance. HEIDENHAIN* first drew attention to this rod-like structure, which is induced more particularly at the basal attached ends of the cell, the rods appearing to run in a direction vertical to that of the tubule. In his experiments he injected sulp-indigotate of soda, and phœnicin-sulphate of sodium, into the circulation of dogs and rabbits, and found that the pigment was excreted by only those sections containing epithelium with the rod-like structure, to the elements of which he ascribed the excretory power. The rod-like structure can be best made out in sections which have been hardened in ammonium chromate solution; it can also be detected in sections which have been otherwise treated, but in the perfectly fresh organ it cannot be seen. It is evidently due to a peculiar disposition of the protoplasm which shrinks into the form described through the action of reagents; and it is probable that KLEIN† is right when he describes that structure as a honey-combed network, and says that the rods are evidently its septa seen in profile. He further showed that the pigment excreted in these regions in the kidney of a cat, into whose circulating blood an ammoniacal solution of carmine was injected, is deposited "*in the interstitial substance between the epithelial cells*," and not in the substance of the cells themselves, as maintained by HEIDENHAIN.

In shape the epithelial cells vary. According to STRICKER, HEIDENHAIN, SPINA, and others, the gland cells of secretory organs undergo remarkable changes in colour, texture, and shape, which are dependent upon the functional activity of the cells; the cylindrical form, opacity, and turgescence of the latter, with the consequent diminution of the size of the lumen, being indicative of an active state; whilst a greater transparency, polygonal form, and large lumen point, to a passive condition of the cells. In general outlines, the cells of this section (the proximal convoluted tubule) are somewhat cubical; towards the neck they decrease very markedly in height, so as almost to appear to cease abruptly there. Throughout the tubule they vary in size, and their apposed sides are not straight, but slightly curved, the convexity of one side fitting into the concavity of that in juxtaposition with it. All the cells possess spherical centrally-situated nuclei.

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* *Archiv für Mikr. Anat.*, Bd. x, 1874.
† *Atlas of Histology*, London, 1880, p. 260.

4.—*The spiral tubule of* SCHACHOWA (p. 111, Fig. II, 4), is situated in that part of the cortex known as the medullary ray, and is thereby distinguished from the proximal convoluted tubule of the labyrinth, of which it is a continuation; on reaching the boundary layer it suddenly becomes very fine, and takes a straight course through that zone as the descending limb of Henle's loop.

In the relative size and shape of its walls and lumen, it resembles the proximal convoluted tubule. Its epithelial cells, in the first part of the tubule, exhibit the rod-like structure very clearly; but this gradually dies away as the boundary layer is approached, and the cells in that locality become finely granular, with occasional exceptions in the form of a coarsely reticular structure (KLEIN). The cells at the commencement of this section are, moreover, very irregular in shape, and SCHACHOWA has pointed out that some of them are elongated columnar cells with concave sides, whilst others are broad with convex sides and convex free surfaces; thereby resembling mushrooms, and accordingly termed the *fungoid cells of* SCHACHOWA. They all possess distinct, centrally situated, spherical nuclei.

5 and 6.—*The descending limb of Henle's loop, and Henle's loop* (p. 111, Fig. II, 5, 6; Figure of H. S. Through Papillary Portion of Human Kidney, *h*). The spiral tubule of SCHACHOWA on reaching the boundary layer in the medullary ray of the cortex, suddenly narrows to form a fine straight tubule which extends through the medullary layer, and enters, for a greater or less distance, its papillary portion; the descending limb of Henle's loop thus marked out, recurves upwards to form Henle's loop; and the recurrent or ascending limb maintains its fine calibre until it reaches the boundary layer. The epithelial cells lining both of these sections become attenuated, and contain oval flattened centrally-placed nuclei. In transverse section they closely resemble capillary blood-vessels, both in size and general outlines; but they can usually be distinguished from the latter by the possession of a membrana propria, and by the greater number of their nuclei.

7.—*The ascending limb of* HENLE'S *loop* (p. 111, Fig. II, 7), on reaching the boundary layer, gradually dilates until it reaches its maximum diameter about the middle of that zone, where its course becomes slightly wavy, and its size varies. Its epithelial cells also become modified into polyhedral forms with a basal rod-like striation; and each cell possesses a spherical strongly marked nucleus, situated towards the free extremity which projects into the lumen.

8.—*The spiral portion of the ascending limb of* HENLE'S *loop* (p. 111, Fig. II, 8). Towards the middle of the boundary layer, the ascending limb becomes more distinctly spiral, and somewhat smaller in diameter. In minute structure its epithelial cells exhibit oval, irregular, and somewhat flattened nuclei placed towards the lumen, which is almost obliterated by the relatively large size of the polyhedral and strongly striated cells. KLEIN* notes that in the human kidney

* *Atlas of Histology*, London, 1880, p. 258.

the cells of this section contain a large amount of brownish granular pigment, and that many of them according to STEUDENER possess short somewhat imbricated processes, due to the variation in height of the cells, which are thus forced to overlap each other.

9.—*The cortical portion of the ascending limb of* HENLE'S *loop* (p. 111, Fig. II, 9), as its name indicates, enters the substance of the cortex, and becoming narrower, straight, or slightly wavy, ascends in the medullary ray where it may become more spiral and somewhat thicker; its lumen diminishes in diameter. Its epithelial cells show the rod-like structure at their attached bases, possess flattened or angular peripheral nuclei, and have occasional imbricated processes.

10.—*The irregular tubule* (p. 111, Fig. II, 10), is a continuation of the last named segment. It leaves the medullary ray to intertwine amongst the convoluted tubules of the labyrinth, and exhibits the following peculiarities:—In outline it is altogether irregular, being wide and angular in some places, narrow and rounded in others; it owes its shape to the extreme variation in the size of its epithelial cells; its lumen being uniformly narrow. The epithelial cells naturally are imbricated, and they display the rod-like structure more markedly than in any other portion of the renal tubule. Each cell contains an oval or angular nucleus towards its periphery.

11.—*The intercalated section of Schweigger-Seidel** (p. 111, Fig. II, 11). This portion is known also as the *distal convoluted tubule.* It agrees in location and structure with the proximal convoluted tubule.

12.—*The curved segment of the collecting tube* (p. 111, Fig. II, 12), is a narrow continuation of the distal convoluted tubule, which passes through the labyrinth to join the next:—

13.—*The straight section of the collecting tube* (p. 111, Fig. II, 13) which is situated in the medullary ray, agrees with the last named segment in its narrow diameter, and small but distinct lumen with its single layer of homogeneous cells, which may vary in shape from regular polyhedral to flattened and even spindle-shaped elements. They all possess well marked spherical or ovoid nuclei, and may show imbricated processes.

14.—*The collecting tube of the boundary layer* (p. 111, Fig. II, 14) is a continuation of that in the medullary ray; its diameter is greater and its lumen larger. Its epithelial cells are short columnar, and closely resemble in other respects those of the foregoing section.

15 and 16.—*The collecting tubes and ducts of the papillary portion* (p. 111, Fig. II, 15, 16, Figure of H. S. Papillary portion of the Human Kidney, *l*, s), are but enlarged copies of sections 13 and 14; the size of their lumen and its epithelial cells, depends upon the diameter of the tube, which increases by accessions of other ducts, until it forms the short large *duct of* BELLINI which open on the papilla.

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* *Die Nieren des Menschen*, Halle, 1865.

KLEIN* has described a delicate structure which lies closely adherent to the surface of the epithelial cells in the lumen of all the sections of the renal tubules in the dog, with the exception of the descending limb of Henle's loop and the loop itself. To this he has applied the name *centro-tubular membrane*, and asserts that every here and there it possesses an oblong nucleus more or less wedged in between the epithelial cells. In the convoluted tubules and the spiral tubule, these nuclei are scarce, but in the ascending limb of Henle's loop, sections 8, 9, 10, and 12 in Fig. II. p. 111, their number is augmented, and may be considerable; the nuclei moreover appear to be placed in depressions in the epithelium. In all the nuclei of the epithelial cells, KLEIN has detected a limiting membrane; and has unequivocally demonstrated the presence of an intranuclear net work, especially in the cells from the human subject.

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* *Atlas of Histology*, London, 1880, pp. 260—1.

THE KIDNEY.

V. S. Human Kidney.

Injected Carmine, and Stained Logwood.
× 145 diameters.

a. Interlobular artery, *af.* Afferent arteriole, *ef.* Efferent vessel, *c.* Capillaries of glomerulus, *t.* Sections of convoluted tubules of labyrinth, *t'.* Sections of tubules of medullary ray.

Etymology.—KID'NEY, *n.*; *pl.* KID'NEYS. See p. 109.

DESCRIPTION.

THE BLOOD-VASCULAR SYSTEM OF THE HUMAN KIDNEY.—In Figs. IV. and V, p. 111, two drawings are given, showing the distribution of blood-vessels within the substance of the Kidney. Fig. IV, copied from LUDWIG'S* diagram, represents clearly the course of the vessels within the medulla and cortex. Fig. V, is a drawing taken from BOWMAN,† to show the disposition of the capillaries within the Malpighian corpuscle; the relations which these tufts of blood-vessels bear to the surrounding and enveloping structures, are fully explained above.‡ In the accompanying plate to this paper, a drawing taken from the cortical region of the human kidney, which had been injected with a carmine mass and stained with logwood, is given, not so much as a means of conveying an idea of the general distribution of the blood-vessels and their relation to the substance of the kidney, as an exact representation of what may be seen in an ordinary preparation. The judicious combination of a large number of such drawings can alone supply the information required in the study of so complex a structure; its value, therfore, lies in the fact that it portrays and localises certain elements, which may always be recognised by careful observation.

A rough dissection of the kidney shows that it receives its blood chiefly by means of the renal artery, which is comparatively large in proportion to the size of the organ which it supplies. This, however, is not its only vascular source; for if the renal artery be tied, the kidneys may be partially injected from the aorta, by means of branches of the lumbar arteries, which are associated with its capsular and extra renal blood

**Art. Kidney, Stricker's Human and Comparative Histology, New-Syd. Soc. Transl.*, Vol. ii, 1872, pp. 83-109.
†*Phil. Trans. Roy. Soc.*, London, 1842.
‡*See this Journal*, pp. 121-122.

supply (LUDWIG). The renal artery divides into four or five primary branches, which enter the hilus between the renal vein and ureter, and may thereafter be seen in the sinus to pass in amongst the infundibula, where they are generally surrounded by a large proportion of adipose tissue. The arteries now divide and sub-divide to enter between the Malpighian pyramids; they are surrounded by longitudinal and circular bands of muscular fibres, and by a delicate connective tissue which accompanies them in their course through the papillary portion. On reaching the boundary layer they are associated together in longitudinal groups which open into incomplete arches, between the cortex and medulla, from which smaller *interlobular arteries* (Fig. IV, *ai*, Fig. V, *a*, p. 111; and drawing of injected and stained kidney, *a*), are given off. These interlobular branches ascend towards the periphery of the cortex, and in doing so give of short transverse branches, one of which is distributed to each Malpighian corpuscle, as its *afferent arteriole* (Fig. V, p. 111, *af*; and drawing of injected and stained kidney, *af*), which breaks up thereafter into a tuft of capillaries in a manner already described. Occasionally the afferent arterioles give off lateral branches before they enter the glomerulus, which ramify over the convoluted tubules in their neighbourhood. On reaching the portion of the cortex which is devoid of Malpighian corpuscles, the interlobular arteries either cease by ending finally as afferent arterioles to those structures; or they may continue towards the capsule, and supply, by a meshwork of capillaries, the convoluted tubules which exist in that region, and may even penetrate the capsule itself, and form part of its capillary system.

The larger arterial arches which subsist between the cortex and medulla, moreover, give rise to a system of vessels which enter the boundary layer and divide into more or less parallel groups which descend towards the papillary portion between the renal tubules, and are continuations of the medullary rays; they thus bestow the peculiar banded appearance to that layer, caused by the so-called *arteriolæ rectæ* (Fig. IV, p. 111, *ar*), whose capillaries form a network with those of the cortical layer, and in descending through the medulla, gradually decrease in number through lateral branches, which they give off to the adjacent tubules, where they form an elongated network. Around the mouths of the ducts they give rise to a close meshwork of capillaries (Fig. IV, p. 111, *vp*).

The *efferent vessel* of the Malpighian corpuscle (Fig. V, p. 111, and drawing of injected and stained kidney, *ef*) breaks up into a dense capillary network of veins which ramify throughout the cortex, supplying all its tubules. The meshes of the labyrinth and periphery are smaller and more regular than those which obtain in the medullary rays, which become elongated (See Fig. IV, p. 111). The capillaries of the periphery of the cortex open into minute veinlets, which in their turn empty into larger vessels like so many rays; these larger vessels are hence termed *Venæ Stellatæ*, or *Stellulæ* (VERHEYEN). Each vena stellata thereafter passes into the labyrinth to become an *interlobular vein* (See Fig. IV, p. 111), and in its passage downwards, receives accessions from the capillary network which supplies the regions around. It accompanies the interlobular artery, and finally terminates at the base of the cortex in one of the larger venous arches situated between the cortex and medulla. From this,

venæ rectæ are given off, which, in their mode of arrangement, closely resemble the arteriæ rectæ; they vary very considerably in their passage through the medulla, and terminate finally in single trunks at the beginning of the papillæ.

THE LYMPHATIC SYSTEM of the kidney, so far as it has been worked out, is manifested in form of a plexus in the capsule, from which free intercommunications place it in connection with lymph spaces which subsist around the convoluted tubules of the cortex. A plexus of vessels also obtains around the larger blood-vessels which enter the medulla; and, according to LUDWIG and ZAWARYKIN, there is a system of intertubular lymph spaces throughout the organ by means of which the deeper lymphatics communicate freely with the superficial capsular system.

THE NERVES of the kidney are derived from the renal plexus, and the lesser splanchnic nerve; they pass directly into the organ along with the blood-vessels, and may be traced as far as their finer ramifications between the medulla and cortex. Their ultimate distribution yet remains to be investigated.

METHODS OF PREPARATION.

EXAMINATION OF THE FRESH KIDNEY.—Procure a fresh kidney with its attached capsule. Slice it into two equal longitudinal halves. The appearances indicated in Fig. I, p. 111, may be easily observed. For the study of the fresh epithelial cells, use a sheep's or a rabbit's kidney from a newly killed animal; make sections with a VALENTIN'S knife, or in the freezing microtome, and examine in a $\frac{3}{4}$ per cent. solution of sodium chloride, or the kidney may merely be scraped, both from the cortex and medulla, and the scraping examined in normal saline solution. The epithelium of the convoluted tubules will appear cloudy, that of the medullary tubules clearer. The basement membrane may also be seen in form of fine homogeneous, sometimes folded, bands. The addition of dilute acetic acid will render the tissues clear, and reveal the nuclei of their cells. Portions of fresh kidney are not suitable for permanent preparations.

LUDWIG'S METHOD OF ISOLATING THE RENAL TUBULES.—Into a flask containing one part of pure hydrochloric acid to four parts of rectified spirit, place a few vertical sections of a fresh kidney. Stopper the flask with a cork, through which a long glass tube is made to pass into the liquid; boil over a sandbath for from one to three hours; replace the mixture with distilled water, and allow the sections to soak for about twenty-four hours. The tubules may then be readily isolated by shaking a section in a test tube with water. Thus obtained, they may be mounted, stained, or unstained, in Farrants's liquid.

INJECTING THE KIDNEY WITH NITRATE OF SILVER is the best method for demonstrating the epithelial lining of the Malpighian corpuscles. The kidney ought to be perfectly fresh and injected *in situ*. For this purpose a rabbit should be killed by bleeding, either by severing the arteries of the neck, or by cutting through the femoral artery whilst

the animal is under the influence of chloroform. A median incision may now be made from the xiphoid cartilage towards the anus; and the abdominal viscera thus laid bare should be gently deflected to expose the kidneys in their natural position. The injection should be made through the renal artery (which may easily be detected as an empty vessel running towards the hilus of the kidney) by means of a large hypodermic syringe, with a half per cent. solution of silver nitrate. The organ will become distended and exhibit an external whitish appearance, when the artery and vein may be ligatured, and the whole removed from the body. Sections should be taken with a VALENTIN'S knife, as freezing is apt to destroy the delicate epithelium by puckering it up. The sections thus obtained must next be exposed to diffuse daylight in distilled water or spirit, for a variable length of time, until they assume a brownish appearance; they may then be removed to spirit, from thence to oil of cloves, and mounted in Canada balsam or dammar solution. The silver nitrate penetrates through the glomerulus and stains the interstitial substance of the epithelial cells, and they are thereby distinctly mapped out from one another.

INJECTION OF THE KIDNEY WITH A GELATINE MASS coloured with carmine or blue, is also best effected *in situ*, to prevent too large an escape; because of the anastomoses which obtain between the renal and lumbar arterial systems. The animal should be kept in a warm bath at a temperature of about 40° C., and the canula of the injecting apparatus inserted into the renal artery close to the aorta. As soon as the mass flows freely from the renal vein, it should be ligatured, and the vessels allowed to fill gradually; after which the artery may be tied, the organ removed, and plunged into methylated spirit. It should be allowed to remain in this for a day, and may then be cut into pieces, and the hardening completed in spirit. Sections may be cut at the end of a fortnight, and mounted stained or unstained in any of the ordinary media.

HARDENING THE KIDNEY may be accomplished by any of the three following methods :—

(i). CHROMIC ACID AND SPIRIT MIXTURE, See pp. 40, 70.—Pieces cut transversely and longitudinally should be treated in a manner precisely similar to that used for the liver (p. 85).

(ii). *Muller's fluid*, See p. 71. Three weeks suffices for the kidney.

(iii). *Ammonium Chromate* is recommended by HEIDENHAIN as a peculiarly useful reagent for hardening the kidney in order to exhibit the basal rod-like structure of the epithelium of its tubules detailed at p. 123. A five per cent. solution in distilled water should be used, and the pieces allowed to remain in it for about two days; they must then be thoroughly well washed to remove all traces of colour, and the hardening completed in 50 per cent. alcohol gradually increased to absolute alcohol, after which sections may be cut and mounted in the usual way.

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THE LUNG.

T. S. Bronchus of Sheep in Lung Tissue.
Stained Logwood.
× 30 diameters.

B. Bronchus, *c.* Cartilage, *a.* Artery, *v.* Vein, *l.* Lung Tissue.

Etymology.—Brŏn'chus, *n.*; pl. Brŏn'chi. [N. Lat. *bronchus*, Gr. βρόγχος, windpipe.]. *(Anatomy)* One of the sub-divisions of the trachea or windpipe.

Lŭng, *n.* [A-S. *lunge*, pl. *lungen*, Icel. *lûnga*, Sw. *lunga*, O. H. Ger. *lungâ*, *lungina*, *lunginna*, *lungunna*, N. H. Ger. and Dan. *lunge*, D. *long*.] *(Anatomy)* "The *lungs* of vertebrated animals are sacs, capable of being filled with air, and developed from the ventral wall of the pharynx, with which they remain connected by a shorter or longer tube, the *trachea*, the division of this for each lung being a *bronchus*. Venous blood is conveyed to them directly from the heart by the pulmonary arteries, and some (generally all, but in some *Amphibia*, such as *Proteus*, part of the blood supplied to the lungs enters the general circulation) or all of the blood which they receive goes back, no less directly, to the same organ by the pulmonary veins" (Huxley*).

With this limited definition of the term *lung*, therefore, the organ so designated becomes the characteristic respiratory apparatus of only the higher groups amongst the forms of animal life. Organs which approach, in structure and function, the lungs of pulmonated *Vertebrata*, exist in certain fishes, but they cannot strictly be termed lungs in conformity with the definition just quoted; for, in the great majority of cases, the air sacs are usually developed from the dorsal, and not the ventral wall of the pharynx, or from the parietes of the œsophagus or stomach; and their blood supply is not derived directly from the heart, but from adjacent arteries, and is commonly returned into the general circulation. In *Amphioxus*, the respiratory function is typically branchial, and hence does not in any way approach a pulmonary system. Amongst the *Marsipobranchii* the organs of respiration consist of sacs flattened antero-posteriorly, placed at the sides of the pharynx with which they communicate directly or indirectly, and with the exterior. The *Elasmobranchii* present from five to seven flattened pouches with transversely-plaited walls, and these open into the pharynx on the one hand, and externally by clefts on the other.

It is not until we arrive at the *Ganoidei*, that organs which at all approach a pulmonary apparatus, are met with. In addition to their branchial system they possess air-bladders, which are

* *A Manual of the Anatomy of Vertebrated Animals*, London, 1871, p. 92.

permanently connected with the œsophagus by an open *pneumatic duct*. In *Polypterus*, amongst these fishes, the air-bladder is sacculated and paired; its pneumatic duct places it in communication with the ventral aspect of the œsophagus, and it thus approaches nearly in localisation the lungs of the higher animals; but it differs from the latter in that its blood supply is not derived *directly* from the heart.

The air-bladder of the *Teleostei*, is usually sacculated, and shows traces of a bipartition in some, whilst in others it presents numerous diverticula. In the Herring its pneumatic duct opens into the dorsal surface of the œsophagus, and in the Cod, the duct becomes obliterated in the adult; whilst in yet others *(Myripristis)* it is brought into close relationship with the organ of hearing, and may even be connected therewith by specially differentiated ossicles *(Siluroidei, Gymnotini, etc.)* It is occasionally absent *(Blennii, Pleuronectidæ, etc.)* The anterior internal walls of the air-bladder usually exhibit *retia mirabilia*, but the blood-vessels from which these are derived do not communicate directly with the heart.

Lastly, in the remarkable group of fishes, the *Dipnoi* which present transitional forms between the *Pisces* and *Amphibia*, *Lepidosiren* not only possesses external and internal gills, but is provided with a well developed pulmonary organ of large size, which, in opening on the ventral aspect of the œsophagus by a glottis, communicating with the buccal chamber into which posterior nares also open, and in returning its blood directly to the left auricle of the heart, is fully entitled to the name of *lung*.

In the adult condition, all the groups of the existing *Amphibia*, and probably even the extinct *Labyrinthodonta*, possess lungs. Some of them (the perennibranchiate *Urodela*) are provided with branchiæ in addition to lungs. The membrane of the lung is at first smooth, but becomes finely sacculated after the termination of the bronchus. In many its distal extremity often retains its simple embryonic condition.

In the *Reptilia* the form of the lung varies considerably in the different groups; thus, the bronchus of snakes *(Ophidia)* opens into an enormously elongated sac the walls of which are produced into numerous diverticula, and greatly sacculated at its anterior end, whilst its posterior extremity may remain smooth. The blood supply of these regions also varies to some extent, the smooth portion usually receiving vessels from the general systemic circulation, whilst the region of the air cells is distinctly pulmonary. In external form, the left lung is usually smaller than the right one, and may be rudimentary or altogether wanting, when the posterior portion of the trachea may become modified to subserve part of the functions of respiration. The Lizards *(Lacertilia)* have much shorter lungs than the *Ophidia*, except in the snake-like forms such as *Pseudopus* and *Lialis;* they resemble those of snakes in other respects; and in some *(Chamelon, Gecko)*, approach to that of birds in the possession of elongated posterior diverticula. In the *Chelonia* and *Crocodilia* the lungs are finely sacculated throughout their extent. The bronchus traverses the length of the lung and becomes less cartilaginous as it approaches the posterior extremity, but it does not branch thereafter. In the former *(Chelonia)* they are fixed against the inner lining of the bony carapace, and are only invested by the peritoneum at their ventral aspect, thus resembling the arrangement which obtains amongst birds.

The lungs of birds *(Aves)* are firmly adherent to the surface of the overlying vertebrae and ribs at their dorsal parietes, and are closely held by muscular elements, which arise from the diaphragm and surrounding parts, to be inserted by an aponeurosis upon their ventral surface. The bronchi enter its substance somewhat centrally, lose their cartilaginous rings, and dilating, traverse the length of the organ; in this course they give off branches at right angles, from which other parallel ramifications proceed and ultimately form networks. The ends of the bronchi terminate in a large delicate posterior air-sac, and in its passage through the organ it gives off other canals which terminate in eight other air-sacs; there are thus altogether nine air-sacs, of these two are abdominal, four thoracic, two cervical, and one interclavicular. From these air-sacs a complicated system of branches extends throughout the body, penetrates the bones, and may even give off subcutaneous diverticula.

In *Mammalia*, the bronchi divide and subdivide dichotomously, and terminate in minute air-lobes and lobules. The microscopic structure and relation of these parts to the subjacent tissues will be fully discussed hereafter.

Description.

The organ of respiration in the highest *Vertebrata* forms a paired system situated in the thoracic region of the body, known as the *lungs*, which lie one on each side of the heart and large blood-vessels, and during the life of the animal completely fill the cavity of the chest; thus it is, that the elastic tissue of the lungs is kept continually on the stretch, and hence constantly tends to recoil, so that if an aperture be made into the pleural cavity the lungs instantly collapse, not on account of the pressure exerted by the atmosphere, for that is obviously the same within and without the lungs, but because the distending force is suddenly withdrawn and permits the elastic tissue to regain its former state on removal of the distorting force.

The lungs are attached in the cavity of the chest by only a comparatively small surface at their flattened inner median portion which is termed the *root*, and the thin membranous fold which extends downwards from that part. At all other parts their surfaces are free, closely adherent to the walls of the chest, and invested by a serous sac, the *pleural membrane*, which is reflected over the sides of the thorax and envelopes the lungs on each side. There are thus two *pleuræ*, one for each lung, and each pleura consists of a parietal portion, the *pleura costalis*, which covers the convex upper surface of the diaphragm, adheres to the sides of the pericardium, and unites with its fellow in the middle line to enter into the formation of the partition, between the two pleural cavities, which is known as the *mediastinum*; and a visceral portion, the *pleura pulmonalis* which covers the lung.

In the section of sheep's lung, which has been depicted, the transverse section of a bronchus is shown surrounded by lung tissue. The epithelium lining its mucous membrane is seen to be composed of a single layer of columnar cells. Klein* has noted that in the larger bronchi the epithelium appears stratified when they are contracted *ad maximum*,

* *Atlas of Histology*, London, 1880, p. 241.

and is seen to consist of only a single layer during distension; and that the columnar cells of the smaller bronchi vary in height according to whether they are distended or contracted *ad maximum*.

The epithelium is supported below by a clear homogeneous looking band, the *basement membrane*, which, according to DEBOVE, consists of a single layer of large nucleated and flattened endothelial plates.

Underneath this comes the *mucosa* which consists of a delicate network of connective tissue fibres and their corresponding corpuscles, amongst which many elastic elements may be detected by their higher refractive indices.

The mucosa is ensheathed in a layer of non-striated muscular fibres circularly disposed, which varies in depth with the state of contraction or relaxion in which it may be.

Outside the muscular coat comes the *submucous connective tissue*, in which small mucous glands obtain. The arrangement of the tissues in this layer depends upon the size of the bronchi. In the smallest bronchi neither glands nor cartilage occur in this situation; in those of larger size the cartilage rings (which consist of hyaline cartilage) are lined by a layer of perichondrium into which the fibrous tissue of the submucous coat often pass by trabecular unions. Outside of the cartilaginous rings the connective tissue forms the *adventitia* of the bronchi, which is richly supplied with networks of elastic fibrils; the adventitia passes thence into the interlobular septa of connective tissue of the lung substance, and in the smaller bronchi merges gradually into the walls of the adjacent alveoli. Where mucous glands occur, they are generally situated between the cartilage plates, and extend towards the adventitia; and occasionally a small proportion of adipose tissue may be found in the submucous coat.

The blood-vascular supply of the bronchi, and their lymphatic and nervous systems will be considered hereafter in continuation of this description.

THE LUNG.

V. S. OF HUMAN LUNG.
Stained Logwood.
× 315 diameters.

a. Alveolus, *a'.* Alveolar Duct in Section, *s.* Alveolar Septum, *f.* Fibrous Outer Capsule of Lung, *p.* Pseudo-stomata, *m.* Circular Muscular Coat of Alveolar Duct, *c.* A Group of Small Polyhedral Cells continued from the Bronchus.

Etymology.—See p. 148.

DESCRIPTION.

THE MICROSCOPIC CHARACTERS OF THE HUMAN LUNG.—The bronchi on their entry into the lung substance ramify by repeated dichotomies at acute angles; their primary divisions forming branches which diverge at narrower angles than their ultimate ramifications. Occasionally three branches arise together; and more rarely still, lateral members are given off from the main trunks. This subdivision goes on without anastomoses, until the final air passages, which have also undergone structural changes, are reduced to minute tubes which vary in diameter from 0·4 — 0·2 mm., and are known as *lobular bronchial tubes*, or *alveolar passages* (F. E. SCHULZE). The alveolar ducts thus formed subdivide and dilate into small conical passages which diverge from each other at acute angles, the basal portion of the cone being distal; to these ROSSIGNOL has applied the term *infundibula;* they do not subdivide any more, but their lateral walls are beset with pouch-like dilatations of spherical or polyhedral shapes*, which range in diameter from 0·1128 — 0·3760 mm., and are known as the *air-cells, pulmonary vesicles, Malpighian cells*, or *terminal alveoli.* ADRIANI has observed, that in the adult body many of the air-cells in the infundibula may coalesce by absorption of their separating walls; and the side walls of many of the alveolar passages may become covered with vesicles so as to somewhat resemble infundibula (FREY).

What has already been briefly described, constitutes the *parenchyma* of the lung substance. It is bound together by a connective-tissue *framework*, and is richly supplied with *blood-vessels, lymphatics*, and *nerves.*

* The shapes of the terminal alveoli are usually spherical, but they become polyhedral when greatly distended; especially the superficial alveoli.

The Framework of the Lung in Man and the higher *Mammalia*, consists of a close investment of fibrous connective tissue, the *pulmonary pleura*, which forms a *capsule* for the whole organ. From this external layer trabecular septa are given off, which divide and subdivide the structure into lobes and these into lobules. Each lobule, composed of the parenchyma of the lung, is thus encased in a tunic of connective tissue belonging to the framework, and its own tissues blend with those of the former in a manner to be herinafter described.

The capsule may be distinguished, in the human lung, into an outer dense layer of fibrous connective tissue containing networks of elastic fibres, and corpuscles, known as the *pleural* layer; and an inner *subpleural* layer which is loosely arranged into lamellæ, between which the corpuscles may be detected, and passes by septal ingrowths, into the substance of the organ dividing it into lobes and lobules. It is moreover in continuity with the connective tissue which surrounds the large blood-vessels and bronchi, and forms the adventitia of their system.*

The surface of the pleural membrane is lined by a layer of endothelium whose cells vary in shape and appearance with the contraction or distension of the organ; they are large, flat, and hyaline, when the lungs are fully distended; smaller, thicker, and granular looking on its collapse. KLEIN†, who has noted these appearances, also states that its interstitial substance places it in communication with the lymph-canalicular system, and this, in its turn, with the numerous lymphatics which obtain in the sub-pleural tissue. In the guinea pig he has described the existence of a varying meshwork of non-striated muscular cells forming lymph sinuses in the pulmonary pleura, which communicate with its free external surface by means of true stomata.

The Parenchyma of the Lung, consists of structures which have already been enumerated. The histology of the bronchi has already been described‡. On reaching the alveolar duct, the epithelial lining of the bronchus loses its ciliated character, and becomes transformed into a layer low polyhedral somewhat columnar cells, each with a well-marked spherical centrally situated nucleus; within the alveolar duct and infundibulum, some of these cells may be seen forming groups *(c)*, and occasionally as isolated elements; they are especially well seen in a profile view of the alveolar wall; but the largest portion of the alveolar walls are lined with placoid shaped cells of much greater size, which closely resemble endothelial plates. In the alveoli themselves these latter predominate; there being but few of the smaller elements left. In appearance the small polyhedral cells are more granular than the placoid plates, and when stained are more readily revealed; they do not seem to be arranged in any definite manner; but their similarity to the forms which exist at the termination of the bronchi has led some observers to suppose that they are distinct from the large flattened cells of the alveoli, and represent a continuation of the bronchial epithelium, whilst to the former a sub-epithelial significance has been delegated. But embryological considerations are adverse to such an ex-

*See this Journal, p. 150.
† *Atlas of Histology*, London, 1880, p. 242.
‡ See this Journal; pp. 149, 150.

planation, for in the lung of the fœtus the alveoli are lined by but one form of cells, the polyhedral granular variety, and KÜTTNER has shown that it is only after respiration, that these become converted into the endothelial form; KLEIN, also, has noted, that during respiration the polyhedral granular forms become placoids when the lungs are distended, and assume their primary shapes on expiration, when the lungs collapse.

Occasionally, between the placoid cells which line the alveolar ducts, infundibula, and alveoli, there may be detected small openings *(p)*; these *pseudo-stomata* as they are termed, correspond to the true stomata of serous membranes; in the specimen of lung from which the drawing was taken, the alveoli were distended *ad maximum*, owing to the death by drowning of the subject from whom the tissue was removed; the pseudo-stomata are therefore well shown; but in contracted lungs they are difficult to demonstrate, and may be reduced to mere specks. They communicate directly with the lymph-canalicular system of the alveolar walls (KLEIN).

The connective tissue with its network of elastic fibres and corresponding corpuscles which obtain in the terminal portion of the bronchi, passes into the walls of the alveolar ducts and infundibula, where it becomes excessively delicate, and is greatly diminished in quantity; the walls being chiefly thickened by circular bands of non-striped muscular fibres *(m)*.

METHODS OF PREPARATION.

THE SILVER PROCESS.—This process is specially adapted for demonstrating the outlines of the epithelial lining of the alveoli, and in conjunction with logwood staining, reveals all the structural details of the framework and parenchyma of the organ; although logwood, if carefully applied alone, will map out the epithelium quite distinctly.

Kill an animal (preferably a cat or kitten), by bleeding, whilst under the influence of chloroform or ether, by severing the carotid or femoral artery. Divide and isolate the trachea immediately below the larynx, and inject it with a quarter per cent. solution of silver nitrate, until the lungs are fully distended, which may be ascertained by opening the thoracic cavity. Now remove the lungs, and suspend them, with a weight attached below, in alcohol (50 per cent. or good methylated spirit), until required. Cut the lung into pieces, which may be done after twenty-four hours, and make sections in the freezing microtome or imbedded in carrot*. The slices must now be exposed to diffuse daylight, until they assume a dark brownish tinge; they may thereafter be mounted in Canada balsam or stained with logwood or picrocarmine and mounted in Canada balsam, or dammar.

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* The lung may be perfectly well cut imbedded in carrot, if the piece of tissue is slightly compressed.

By this method the interstitial substance of the epithelium will be rendered a dark brown, and their outlines thus clearly mapped out; and if a stain be used in addition, it will colour the nuclei, and the connective tissue and other elements generally.

HARDENING THE LUNG, may be accomplished by any of the following methods: it is, of course, desirable to procure a perfectly fresh organ; to kill the animal distend its lungs through the trachea with the hardening reagent, and suspend them a quantity of the same fluid, until the process has been completed.

1°. *Methylated Spirit.*—A time varying from two to four weeks suffices; and if the process is carefully watched, very good results may be obtained.

2°. *Chromic Acid.*—A quarter per cent. solution should be used; the organ filled through the trachea, and suspended in the fluid in a wrapping of cotton wool, and the fluid changed at the end of eighteen hours. At the end of about four weeks, the tissues may be cut into pieces, each about half an inch square, and the hardening completed in spirit. In this they may remain until required.

3°. *Chromic Acid and Spirit**. Distend the lungs with the fluid and suspend them in a large quantity of it for twenty-four hours; change the fluid, and after a period of three days cut the organ into small pieces, and place them in fresh fluid for a week; wash thoroughly, and transfer to alcohol until required. (STIRLING).

Sections cut from tissues which have been hardened by any of the foregoing plans, may be stained in logwood, picrocarmine, or carmine, and mounted in Canada balsam or dammar. No. 3 is the best hardening process.

* See this Journal, pp. 40, 70.

THE LUNG.

V. S. Lung of Cat.
Injected Carmine.
× 145 diameters.

a. Artery, *v.* Vein, *c.* Capillaries.

Etymology,—See p. 148.

Description.

The Blood-Vascular System.—Two distinct systems of blood-vessels are distributed to the lungs; one termed the *bronchial*, and the other the *pulmonary* system. The former is concerned chiefly with the nutrition of the organ, whilst the latter subserves one of the most important functions of the animal economy in the means which it provides for the aeration of the blood. Cohnheim and Litten have denied the statement that the ultimate capillaries of the two systems form anastomoses; but it is highly probable that such a union does exist (Hoyer, Köster).

The bronchial arteries arise as ramifications of the systemic circulatory organs, in from one to three branches of the aorta, or from an intercostal artery, and thereafter proceed through the substance of the lungs in association with the bronchi, to the lymphatic glands of which they are distributed. In addition to this they supply the coats of the large blood-vessels which obtain in the connective tissue and muscular walls of the air-tubes, and form a capillary network which spreads over the mucous membrane of those tubes, and is ultimately continuous with the capillaries of the pulmonary system. Branches are also given off, which enter into the delicate interlobular tissue of the organ; and a plexus is formed beneath the pleural investment, the capillaries of which may be distinguished from those of the pulmonary system by their wider arrangement and more or less tortuous course, as well as by their connection with the superficial bronchial veins. The pulmonary pleura is further nourished by twigs which owe their origin to the adjacent intercostal arteries, which penetrate through the *ligamentum latum pulmonis* (Turner).

The venous blood of the bronchial system is collected by a superficial and deep set of vessels which unite at the root of the lung, and pass into

the *vena azygos* on the right, and usually into the superior intercostal vein on the left side. Part of the blood finds its way into the pulmonary circulation through the capillary anastomoses with that system.

The pulmonary artery, on its entry into the lung, follows the course of the bronchial tubes, dividing and subdividing repeatedly without reference to the branching of the air-tubes. No anastomoses are formed until the region of the alveoli is reached, where a dense capillary network besets the walls of the bronchi and air-cells.

The position of the larger pulmonary arteries and veins, with reference to the bronchi, may be clearly made out in a section such as that depicted in this Journal of the sheep's lung. There it may be seen that the inter-lobular connective tissue becomes continuous with their adventitia. KLEIN* has observed, especially with reference to the guinea pig, that the circular muscular coat of the branches of the pulmonary artery is often interruptedly continuous, so that at places the adventitia comes into immediate contact with the intima.

The most important portion of the pulmonary circulation,—its capillary network, is very characteristically displayed. The capillaries themselves do not differ in intimate structure from those of other organs. They form a dense network between the pulmonary artery and pulmonary vein. To trace their disposition, it is necessary to have recourse to the methods of injection with coloured masses, and even then it very much depends upon the state of expansion or contraction of the organ. In a fully distended lung the capillary network is seen to form a honeycombed arrangement in each alveolus, the vessels are either straight or slightly wavy; whilst in a contracted specimen they are, of course, very wavy. They lie immediately beneath the epithelial lining of the alveoli, and are thus brought into the most intimate relationship with the inhaled air. The afferent arteriole which gives rise to the capillary network usually serves its purpose for two or more alveoli, and the efferent vein, which conveys the blood away from each diminutive group thus formed, generally passes out at the opposite side to the arteriole. The capillaries of the interalveolar septa, are worthy of special attention; they are very often somewhat twisted, and sometimes dip from one into another alveolus.

It has been observed by ROSSIGNOL that the smaller pulmonary veins, instead of accompanying the arteries and bronchial ramifications in every instance, frequently diverge to take an independent solitary course, and thereafter join some deeper vein situated near a bronchial tube, and form many lateral communications. The veins do not possess valves; they finally unite, and accompany the artery to leave the lung at its root.

THE LYMPHATIC SYSTEM.—The elaborate researches of KLEIN, which are summarised in his *Atlas of Histology*, pp. 245—247, have revealed that the complicated lymphatic system of the lung may be considered under the three following heads:—

**Atlas of Histology*, London, 1880, p. 245

1°. The *subpleural* or *superficial* (WYWODZOFF) lymphatics, which consist of a dense network of vessels, many of which possess valves, communicate by rootlets with the pleura, but more particularly with the lymph-canalicular system of the walls of the alveoli beneath the pleura. From this subpleural plexus numerous vessels pass through the interlobular connective tissue to become continuous with the next system.

2°. The *perivascular* lymphatics originate in rootlets from the lymph-canalicular system of the alveolar walls, and thereafter accompany and often invaginate the branches of the pulmonary artery and vein. Their larger branches possess valves. They sometimes "*form a dense network of intercommunicating sinuses in the sheath of the large branches of the pulmonary artery*" (KLEIN).

3°. The *peribronchial* lymphatics, the *deep* lymphatics of the bronchi, form a plexus of valvate lymphatic trunks, which accompany and anastomose freely with the perivascular lymphatics, and pass through the interstitial connective tissue of the lungs towards the bronchial glands. The walls of all the lymphatics are constituted of a single layer of endothelial plates.

THE NERVOUS SYSTEM.—The innervation of the lung is a subject which has received more successful attention at the hands of the physiologist than those of the anatomist. Beyond the fact that its tissues are supplied chiefly by the vagi, and partially from the sympathetic system, very little is definitely known.

The fine nervous elements have been traced along the bronchial tubes, and REMAK has stated that white fibres, belonging to the pneumogastric, may be followed along the air passages to the superficies of the organ; and that greyish filaments, evidently of sympathetic origin, which exhibit minute ganglionic swellings, occur both on the bronchial tubes and the pulmonary pleura. ARNOLD also has remarked that the pulmonary nerves of the frog end in pyriform cells.

METHODS OF PREPARATION.

INJECTING THE BLOOD-VESSELS.—Satisfactory results can only be attained, where the organ is procured perfectly fresh; it is therefore advisable to use the lungs of some animal which can be killed for the purpose.

A carmine and gelatine mass should be prepared and kept fluid at a temperature of about 40°C.; the canula of the injecting apparatus should be inserted into the pulmonary artery, which may easily be exposed by opening the pericardial cavity, and the injection commenced. The distension of the organ should be carefully watched. Precautions should be taken to keep the animal or organ in a warm bath previous to injecting. In order to display the capillaries of the alveoli to the greatest advantage, the air-cells of the lung should be also distended.

The most effective plan, and one which can always be relied upon, is to detach the organ from the body with the trachea attached to it, and hang it on a support. Before it has had time to become cold, a quantity

of cocoa butter, melted at a low temperature, should be poured into the trachea through a small glass funnel. The weight of the cocoa butter will be sufficient to carry it into the alveoli; great care must be taken not to overdistend them.

When the preparation has become quite cold, it will be found to be thoroughly filled and supported by the cocoa butter, so that it can be cut up into pieces of about half an inch square with the utmost facility. The pieces should be placed in spirit which should be renewed once every twenty-four hours for the first three days, after which they may remain in the final change of spirit until required.

Thus prepared the tissue may be cut into sections imbedded, in a piece, of carrot or otherwise.

MOUNTING THE SECTIONS.—1°. Soak for an hour in strong methylated or rectified spirit, to remove any water which the sections may contain. 2°. Float the sections on to the surface of a watch-glass full of oil of cloves; this process clears the tissues, and softens the cocoa butter which fills up the spaces in them. 3°. As soon as the slices have been thoroughly permeated by the oil of cloves (i.e., when they sink), they should be transferred to spirits of turpentine, and allowed to remain therein until all the cocoa butter has been dissolved out of the tissues. During this process, they ought to be carefully watched as they are apt to curl up if subjected to the prolonged action of turpentine. 4°. From the turpentine, the sections should be mounted in Canada balsam or dammar solution.

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THE THYROID BODY.

H. S. OF HUMAN THYROID BODY.

Stained Carmine and Sulph-Indigotate of Soda.

× 150 diameters.

a. Transverse Section of Artery in Superficial Connective Tissue, *a'*. Transverse Section of Artery in Intervesicular Connective Tissue, *v*. Transverse Section of Vein in Superficial Connective Tissue, *V*. Vesicle, *b*. Basement Membrane, *e*. Epithelium of Vesicle, *e'*. Epithelium of Vesicle shown as a Membrane, due to Superficial Tangential Section of a Vesicle, *c*. Superficial Connective Tissue, *c'*. Intervesicular Connective Tissue, *c''*. Interlobular Trabecula of Connective tissue.

Etymology.—THY'ROID, *a*. [Fr. *thyroïde*, Gr. Θυρεοειδής, shield-shaped, from Θυρεος, a large, oblong shield, from Θύρα, a door, and εἶδος, form]. Shaped like a shield.

COMPARATIVE ANATOMY.—A phylogenetic consideration of the development of the thyroid body leads us with W. MÜLLER[1] to a group of organisms, whose place in nature wavers between the two great divisions of the animal kingdom. Amongst the *Ascidians*, a groove-like involution of the ventral aspect of the branchial sac, which is bounded by two lateral folds, has been detected, and is generally known as the *endostyle* or *hypopharyngeal groove;* it remains in permanent continuity with the pharyngeal sac, to which it evidently functions as a mucous gland. W. MÜLLER[2] demonstrated the existence of a very similar organ in *Amphioxus*, and named it the hypopharyngeal groove; he also showed, that in the Ammocœte condition of the Lamprey, a singular groove-like diverticulum, extends from the ventral walls of the throat between the second and fourth visceral clefts. In its ontogeny, this depression becomes gradually reduced to a pore which is situated between the third and fourth permanent visceral clefts, and the organ thus partially cut off, develops paired anterior and posterior cornua, and a median spiral portion, until in the adult condition its opening into the pharynx becomes obliterated, and it takes on the vesicular structure so characteristic of the thyroid body, and remains a ductless gland.

The existence of a thyroid body amongst fishes was first accurately determined and noted by SIMON.[3] His investigations, however, did not

[1] *Die Hypobranchialrinne d. Tunicaten, Jenaische Zeitschrift*, Bd. viii, 1872.
[2] *Ueber die Entwickelung der Schilddrüse, Jenaische Zeitschrift*, Bd. vi, 1871
[3] *On The Comparative Anatomy of the Thyroid Gland, Phil. Trans. Roy. Soc.* London, 1844, p. 299.

lead him further than the statement that "the questionable trace of a thyroid, noticed in the *Petromyzon marinus*, was in a depression of the base of the skull, between the palate and the posterior confluence of the branchial veins; it would resemble the above in being single, but otherwise would be nearer to the thyroids of the osseous fishes."[1]

F. M. BALFOUR[2] in his researches on the embryology of the Elasmobranch fishes, asserts that the Thyroid body is heralded in the early stages of its development, by a diverticulum from the ventral aspect of the throat in the region of the mandibular arch. In *Scyllium* and *Torpedo*, the organ becomes solid, but still retains its attachment to the walls of the pharynx; it thereafter becomes divided into lobes and lobules, and finally loses its connection with the pharyngeal parietes, and develops a lumen.

SIMON[3] has remarked, that the Thyroid body of fishes is to be sought for amongst the different members of that group in three situations. In some, as in *Perca*, *Mugil*, and *Trigla*, he failed to discover any structure which bears the slightest resemblance to the Thyroid. In the *Eel* and in certain Elasmobranchs, it obtains as a single median organ in connection with the anterior surface of the intermediate cartilages of the branchial arch, and is very readily exposed. In the *Gadidæ* (Cod, Haddock), it forms a paired body, the two parts of which lie one on each side of the anterior end of the first branchial arch. In the *Carp*, *Anableps*, the *Pike* and *Exocetus*, the gland lies upon the pterygoid muscle, and is often deeply imbedded between the latter and the outer end of the branchial bone.

In his elaborate memoir on *Lepidosiren paradoxa*, BISCHOFF described a minute glandular body, adjacent to the anterior extremity of each cornu of the hyoid bone, which is devoid of any excretory duct; SIMON'S[4] observations with regard to *Menopoma* and *Menobranchus* so nearly accord with this, that he is fully justified in assigning to it the name of thyroid body.

Amongst the *Amphibia* the thyroid body arises as an involution of the region of the mandibular arch. It early develops a two-fold epithelial wall which brings the throat into peculiar relationship with the nervous stratum of the epidermis; the significance of this unique circumstance is still an enigma. Later on it loses its relation to the epidermis, and continues, as in other instances,—an appendage of the pharyngeal cavity.

In the common Frog, SIMON[3] has stated that the thyroids "are situated on the carotid arteries, just beside the cornua of the hyoid bone, one on each side." Of this, he speaks with absolute certainty, for he notes that

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[1] *Loc. cit.*, p. 300.

[2] *A Monograph on the Development of Elasmobranch Fishes*, London, 1878, pp. 223—225.

[3] *Loc. cit.*, pp. 299—300.

[4] *Loc. cit.*, p. 298.

CARUS[1], although he had discovered them, points to them with hesitation and vagueness. LEYDIG[2] says that the thyroids of *Batrachia* generally consist of only three large and separate vesicles, which are invested by a close network of blood-capillaries, and contain a finely granular fatty material. The observations of HUXLEY and MARTIN[3] and ROLLESTON'S figure[4] are, in like manner, vague and unsatisfactory. In contradistinction to all this, W. MÜLLER,[5] whose statements tally with those of SIMON, observes that the thyroid body lies, in young frogs, on the two sides of the body of the hyoid bone, immediately above the attachment of the *cornua thyreoidea*, and is walled in on all sides by muscular fasciculi, and enveloped in a delicate capsular investment, from which blood-vessels enter its substance accompanied by connective tissue, and divide it into vesicular lobes, each chamber of which possesses a *membrana propria*, a lining of unstratified cubical epithelium, and contains a homogeneous, colourless, somewhat viscous fluid. Such a description makes it extremely probable that the structures in question form the thyroid body, and the recent researches of BABER[6] leave no room for doubt that such is their significance.

In the *Reptilia*, the thyroid body occupies a median position just above the base of the heart, between the carotid arteries. It has often been mistaken for the thymus gland, and is so figured by BOJANUS in his celebrated monograph.[7] Amongst the *Lacertilia* it may remain median and unpaired, as in *Teius*, *Gecko*, and *Chamæleon*; or double as in *Monitor*, and *Istiurus*. TREVIRANUS,[8] in his dissection of *Chamæleo carinatus*, described an organ which he rightly understood to be the thyroid body, close to the hyoid bone, under the sacciform dilatation of the larynx.

The thyroid and thymus glands are so closely associated in the *Ophidia*, that they have very often led to misleading interpretations. On the whole, SIMON'S notes seem to be most accurate; he says:—[9] "The following description applies to all the true serpents:—"The gland lies, as in the Crocodile, just above the base of the heart between the right and left carotid arteries; it is a little hidden by the thymus of each side, which lies on the carotid for some distance from the pericardium upwards; and in those genera which possess a fat body (as is, for example, the case with the Python) this large organ lies conspicuously in front of both the thymus and thyroid."

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[1] *Vergleichende Anatomie*, § 741.
[2] *Lehrbuch der Histologie*, 1857, p. 376.
[3] *A Course of Elementary Instruction in Practical Biology*, London, 1877, p. 181.
[4] *Forms of Animal Life*, Oxford, 1870, Pl. iii, p. 181.
[5] *Jenaische, Zeitschrift für Medizin und Naturwiss.*, 1871, Bd. vi, p. 438.
[6] *Phil. Trans. Roy. Soc.*, London, 1881, pp. 579—580, and Plate 68, Fig. 1, i.
[7] *Anatome Testudinis Europaeae*, Vilnae, 1819—21, Figs. 66, 156, et 173.
[8] *Beobachtungen aus der Zootomie*, p. 87.
[9] *Loc. cit.*, p. 298.

Amongst the *Aves*, we are indebted for our knowledge of the thyroid body to W. MÜLLER[1]. The results of his investigations show that towards the end of the second, or beginning of the third day of incubation, in the egg of the Fowl, an outgrowth of the hypoblast in the pharyngeal region takes place, opposite to the origin of the anterior arterial arch. The fourth day shows this protrusion to consist of a solid mass of cells, which becomes bilobed and separated from the epithelium of the throat on the fifth day. The seventh day shows that it has shifted backwards, and that its two divisions have become distinct from each other. On the ninth day a capsular investment of connective tissue grows around its divisions, and sends in inward trabeculæ which subdivide its substance into solid lobules of cells. No further changes of importance take place until about the sixteenth day, when it is found in the condition of a paired organ with hollowed vesicles; each of the latter being provided with a membrana propria, and separated from each other by a delicate connective tissue. In its future growth, it gradually passes back to its original locality, at the point of origin of the anterior arterial arch.

The development of the thyroid body amongst the higher *Vertebrata* has been studied by KÖLLIKER[2] and HIS[3]. Their researches show that a caecal invagination takes place at the juncture of the anterior pair of aortic arches, but that it soon becomes solid, separates, and shifts its position to the ventral aspect of the trachea, where it undergoes, first of all, a primary bi-partition which, however, is not complete, the two portions being united by an isthmus; and that it afterwards becomes developed into a vesicular organ supported by and invested in a stroma of connective tissue, with its blood-vascular, lymphatic, and nervous systems.

DESCRIPTION.

ON THE MINUTE STRUCTURE OF THE HUMAN THYROID BODY.—It will be gathered from the foregoing notes on the comparative anatomy and development of the thyroid body, that it consists essentially, as in all glandular structures, of a framework and a parenchyma.

Its early development shows, that it consists of a solid mass of subspherical cells, derived from the hypoblastic layer of the anterior end of the foregut of the embryo, to which the name *alveolar organ* may with justice be applied, inasmuch as in its subsequent growth it is invaded by mesoblastic ingrowths of connective tissue which first of all envelop the alveolar organ, and then penetrate its substance, dividing it into lobes and lobules, and these into vesicles or alveoli. This state of affairs pro-

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[1] *Ueber die Entwickelung der Schilddrüse, Jenaische Zeitschrift*, 1871, Bd. vi.

[2] *Grundriss der Entwickelungsgeschichte d. Mens. u. d. höheren Thiere*, Leipzig, 1880, p. 336.

[3] *Anatomie menschlichen Embryonen*, I, *Embryonen d. ersten Monats*, Leipzig, 1880.

gresses actively, until the organ has reached its full maturity, which is probably attained at birth (FREY[1]); it thereafter continues to grow tardily, and possibly to degenerate. It thus happens, that whilst some of the alveoli are large, others are comparatively diminutive, especially in early life, and that no definite statement can be made respecting the size of the alveoli, nor their relations to one another. This explanation of its irregular development and degeneration, accounts also for the apparent confluence of some of the alveoli, even in the adult conditon, as pointed out by ZEISS[2] and BABER.[3]

The Framework consists of a capsular connective tissue, with its corresponding corpuscles, arranged in numerous lamellæ, in which many elastic fibrils intertwine. From this superficial boundary *(c)* septa of varying breadth are given off, forming interlobar strands *(c″)* and these, in their turn, ramify to divide the gland into lobules. The interlobular connective tissue merges into a meshwork of fine lamellæ which circumvest the alveoli, and thus produce an intervesicular or interalveolar framework *(c′)*, which varies in quantity in different animals; amongst the *Mammalia* it reaches its maximum in Man. (KÖLLIKER.)

The Alveoli vary in size, even within the same lobule, but to a less extent in the same than in different individuals.[4] In shape they may be oval or spherical, or any of the forms which result from their compression. These two factors (size and shape) are dependent upon the state of active or passive secretion of the organ (KLEIN),[5] and most of them are provided with a central cavity or lumen.

KLEIN[5] states, that each alveolus is limited by a *membrana propria*, composed of a network of nucleated flattened cells, from which nucleated spindle-shaped or branched elements extend to, and between, the epithelial lining of their cavitary system.

The Epithelium lining each alveolus consists of a single layer of low columnar or cubical cells with slightly oval nuclei, which upon distension of the alveoli assume polyhedral forms with spherical nuclei (KLEIN).

To the *Alveolar Contents* which are viscid, semi-fluid, homogeneous, and tinged with a yellowish hue, the name *colloid matter* has been given. Often, spherical or ovoid, highly refractive accumulations obtain within the alveoli, and, together with an abnormal amount of secretion, distend them very considerably. In this state, the interalveolar connective tissue suffers by undue compression, and the whole organ may increase very largely in size, and give rise to the pathological condition known as *goitre* or *bronchocœle*. BABER[6] has observed that numerous large granular nucleated cells occur in the interalveolar septa, and migrate into the

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[1] *The Histology and Histochemistry of Man*, London, 1874, p. 443.
[2] *Mikros. Untersuch. ü. den Bau der Schilddrüse, Inaug. Diss.*, Strassburg, 1877.
[3] *Phil. Trans. Roy. Soc.*, London, 1881.
[4] FREY, *loc. cit.*, p. 441, gives the following dimensions for the alveoli:—They vary from 0·0501—0.1026 mm. in. diameter.
[5] *Atlas of Histology*, London, 1880, p. 433.
[6] *Quarterly Journal of Microscopical Science*, No. lxvii, July, 1877.

cavities of the alveoli where they undergo degeneration; he has called these elements *parenchymatous cells*. He also discovered quantities of blood within the alveoli, the coloured corpuscles of which greatly preponderate, and occur in all stages of disintegration. To this phenomenon he ascribes the yellowish colour of the alveolar contents which are thus tinged by haemoglobin or one of its derivatives, and unmistakably points out, that one of the functions of the thyroid body is to remove and to destroy the coloured blood corpuscles.

The *Blood-Vascular System* of the thyroid body is manifested in a rich circumalveolar network of capillaries to which afferent and efferent vessels proceeed by means of the connective tissue framework.

BABER[1] has described a *Lymphatic System*, which pertains in form of walled sinuses between the alveoli and interalveolar septa which empty into lymph vessels with valves, contained in the interlobular septa, and forming perivascular sheaths around the arterial branches. The efferent lymphatics form a network in the capsule of the organ; they contain a substance which closely resembles that of the alveolar contents, and BABER has been led to conclude from this and from the peculiar arrangement of the circum-alveolar sinuses, that they are concerned in the removal of the alveolar contents.

METHODS OF PREPARATION.

STAINING WITH CARMINE AND SULPH-INDIGOTATE OF SODA. See p. 40 of this Journal. It will be observed that the carmine has stained the epithelial lining of the alveoli, as well as all the nuclei of the connective tissue exclusively, and that the blue dye has acted upon the fibrous portion of the connective tissue, and the so-called colloid matter of the alveoli.

HARDENING THE THYROID BODY.—(i). Place in *Müller's fluid*[2] for three weeks, and then transfer to spirit until required. (ii). [3] Place in *Chromic and Spirit fluid* for two weeks, and complete the hardening in spirit.

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[1] *Quarterly Journal of Microscopical Science*, No. lxvii, July, 1877.

[2] *See this Journal*, p. 71.

[3] *See this Journal*, p. 70.

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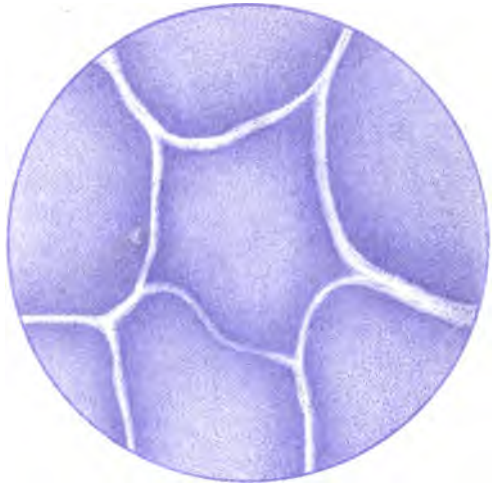

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J.W.Watson.del.et lith.

H. S. THYMUS GLAND.

From the Calf

X 65

Watson & Son. Chromo Lithogrs. Marshall St. Birm.

THE THYMUS GLAND.

H. S. THYMUS GLAND OF CALF.

Stained Logwood.

× 65 diameters.

Etymology.—THY'MUS, *n.* [N. Lat,, Gr. *θύμος*, from *θύειν*, to sacrifice, to smell.] (*Anatomy*).—HUXLEY has described the thymus gland, as an organ developed in the neighbourhood of the primitive aortic arches of all vertebrated animals except *Amphioxus;* double in most of the lower *Vertebrata*, but single in the *Mammalia*, and belonging to the category of lymphatic glands.

The thymus is, amongst the higher *Vertebrata*, an organ of early life, inasmuch as in later times it becomes the seat of fatty degeneration, and usually disappears altogether in the fully matured animal. In the human subject it reaches its maximum development at about the second year of infancy; it ceases to grow thereafter, and gradually degenerates. After the twenty-fifth year it rarely obtains, except as a mere vestige of glandular tissue incorporated in a mass of fat. In its fully developed condition it forms a bilobed organ, of a greyish-pink colour and pulpy consistence, situated in the anterior mediastinum beneath the upper extremity of the sternum.

DESCRIPTION.

The thymus gland consists of a framework of ordinary connective tissue which divides the gland substance into lobes and lobules, and these last into follicles. The gland substance itself, consists of a retiform tissue, in the meshes of which numerous lymph-corpuscles lie imbedded, and give place here and there to cells of other forms.

The *Framework* forms a capsular investment for the whole organ, from which large septa pass into the gland substance and divide it into lobes; from these strands secondary septa are given off, which subdivide the lobes into lobules. These interlobar and interlobular trabeculæ are formed of lamellæ of ordinary gelatigenous connective tissue with their corresponding corpuscles, and a few fine interlacements of elastic fibrillæ. In this respect they are essentially similar in structure to the capsular tissue, which, however, possesses a slight excess of elastic elements.

From the interlobular septa, other branches proceed, which subdivide the lobules into follicles of irregular, cylindrical, or oblong shapes. It may be observed that towards the periphery, the follicles are sometimes of tolerably regular polygonal forms. Elastic fibrils, moreover, are absent from the interfollicular septa, or only occur very sparingly.

KLEIN[1] has noted that "the capsule is surrounded by a continuation of the pleura, a delicate connective-tissue membrane with networks of

[1] *Atlas of Histology*, London, 1880, p. 165.

elastic fibrils and numerous capillary blood-vessels, a plexus of nerve fibres, and a few lymphatic vessels; towards the pleural cavity it is covered with a single layer of endothelium."

The Gland Substance is arranged within each follicle into an outer denser layer, which is termed the *cortex*, passing gradually into a *medullary* more loosely disposed portion. This is shown very clearly in the illustration, which represents a polygonal follicle from the peripheral region of the organ surrounded by parts of other follicles and the interfollicular connective tissue. According to WATNEY the medullary portion of neighbouring follicles is often continuous, and the cortical part usually exceeds the medulla in quantity.

Both cortex and medulla consist of a reticular network of flattened plate-like nucleated cells, from which fine thread-like and membranous processes extend to produce the meshwork; they thus retain the primitive embryonic condition, and thereby differ from the elements of ordinary retiform tissue (AFANASSIEW).

The meshes of the reticulum lodge :—1°. Numerous lymph-corpuscles; these are spherical in shape, with large well-defined nuclei surrounded by a narrow layer of clear protoplasm. In the cortical region they are very numerous, and almost completely fill the interspaces; they are also the predominant elements of the medulla, but are not quite so closely packed as in the cortex.

2°. Large endotheloid cells with well marked oval transparent nuclei. These occur but sparingly in the cortex, but are stated by KLEIN[1] to almost fill each reticular space, and to occur at regular intervals, thereby confining the lymph-corpuscles to a narrow zone between them and the branches of the reticulum, and imparting a comparatively transparent aspect to the medulla. WATNEY has noted that some of these endotheloid cells are occasionally granular, and possess from one to three nuclei; and other elements, from these to multinuclear giant cells, are by no means of rare occurrence.

3°. In the medullary region there also occur peculiar cells, which are known as the *concentric corpuscles of Hassall*. Each of these consists of a central nucleated granular protoplasm, around which flattened nucleated plates are arranged in concentric series. AFANASSIEW is of opinion that they are produced by the proliferation of the endothelium of blood-vessels, whose cavities thus become obliterated, and form a solid body composed of concentric lamellæ. WATNEY, on the other hand, supposes that they are concerned in the production of the connective tissue trabeculæ and blood-vessels. They seem to me, however, to approach in structure the nerve endings of certain visceral glands, such as the pancreas of the cat, etc., and although they differ from Pacinian bodies in size, the dissimilarity of their location (the one within the meshes of a reticular tissue, and the other in the connective tissue proper) is not sufficient to decide against their probable nervous origin. The reaction of gold chloride would perhaps help to elucidate this question.

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[1] *Loc. cit.*, p. 166.

The Blood-Vascular System is supported by the connective tissue framework of the organ. The blood-vessels usually penetrate to the centres of the follicles, and from these capillaries radiate to the cortex. Within the gland substance their outer coats receive accessions from the reticular tissue of which it is partially formed.

The Lymphatic System.—KLEIN has stated that lymph sinuses may be sometimes seen surrounding a portion of the periphery of the follicles. According to HIS, each large blood-vessel is accompanied by two or more lymphatics, which arise from an interlobular plexus; and this in its turn is in communication with the peri-follicular system.

The Nervous System.—Beyond the fact that branches from the phrenic and descendens noni supply the capsule, and that filaments from the pneumo-gastric and sympathetic find their way into the gland, nothing certain is known regarding the nerves.

The Development of the Thymus Gland has been studied by KÖLLIKER and HIS, and more recently by STIEDA. It has been held to be a lymphatic gland, and concerned with the elaboration of the blood in some way. KÖLLIKER[1] has attempted to show that the opinion of its entire mesoblastic origin is probably incorrect, for he found that in the Rabbit it presents in its earlier stages, an epithelial character; and he refers to the investigations of REMAK, which show that numerous glandular bodies are produced, which would occupy the region of the anterior mediastinum, during the degeneration of the posterior visceral clefts of the embryo.

STIEDA'S[2] observations, made on the Sheep and Pig, confirm KÖLLIKER'S view; the thymus is stated to arise as a bilobed projection from the epithelial remains of a pair of visceral clefts. In the Sheep these are hollow but eventually become solid; in the Pig they are always solid; in both cases, however, they finally unite in the median line.

KÖLLIKER is of opinion that the entire gland substance of the organ is of hypoblastic origin; but STIEDA, and HIS, assert that only the so-called concentric corpuscles are epithelial, and that the adenoid tissue with its contained lymph elements are of mesoblastic derivation.

METHODS OF PREPARATION.

STAINING WITH LOGWOOD. See this Journal, p. 85, etc.

HARDENING THE THYMUS GLAND.—The gland of a calf is preferable to that of the human infant because it can always be freshly procured. Those of the young rabbit, kitten, or pup, do not show the concentric corpuscles very clearly.

(i). *Chromic Acid and Spirit Mixture.*—Follow the directions given at p. 182 of this journal.

(ii). *Picric Acid.*—Harden small pieces in a saturated solution of picric acid made in cold water, and kept saturated by an excess of crystals, for twenty-four hours; transfer to methylated or rectified spirit until required. Sections from tissues thus prepared may be stained with picro-carmine and mounted in Farrants's solution.

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[1] *Entwickelungsges d. Mens. u. d. höheren Thiere*, Leipzig, 1879, p. 881.
[2] *Unters. über d. Entwick. d. Gland Thymus, etc.*, Leipzig, 1881.

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THE PANCREAS.

T. S. OF HUMAN PANCREAS.
Stained Carmine.
× 333 diameters.

c. Interlobular Connective Tissue, *c'.* Interalveolar Connective Tissue, *t.* Gland Tubuli or Alveoli, *d.* A Lobar Duct.

Etymology.—PĂN'CRE-AS, *n.* [Gr. πάγκρεας, from πᾶν, all, and κρέας, flesh, meat; Fr. *pancréas*]. *(Anatomy).*—The human pancreas "is a long, narrow, flattened gland of a reddish cream colour, larger at one end than at the other, and lying across the posterior wall of the abdomen, behind the stomach, and opposite the first lumbar vertebra. Its larger end, the *head*, turned to the right, is embraced by the curvature of the duodenum, whilst its left or narrow extremity, the *tail*, reaches to a somewhat higher level, and is in contact with the spleen."[1] The pancreas affords a good example of the compound tubular type which, with varying degrees of complexity, is characteristic of all save lymph- and blood-glands.

DESCRIPTION.

ON THE MINUTE STRUCTURE OF THE PANCREAS.—1°. *The General Arrangement of Parts.*—The structures which combine to form the aggregate gland-mass admit of a three-fold division into:—(α) *A framework* of connective tissue which also serves as the carrier of the blood-vessels, lymphatics, and nerves. (β) *A canalicular system* composed of the pancreatic duct and its ramifications. (γ) *An alveolar system.*

THE FRAMEWORK consists of a thin capsule of fibrous connective tissue, chiefly of the gelatigenous variety, arranged in form of a lamellar coat, with flattened, sometimes much branched interlamellar corpuscles. From this external investment, inward branches are given off which penetrate the gland substance and divide it into lobes and lobules. The interlobar septa are relatively wider than the interlobular, and serve to carry the larger ducts of the canalicular system. The interlobular tissue gives off delicate strands which envelop the gland alveoli, and in some places seems to be composed chiefly of branched connective-tissue corpuscles, with but a scanty proportion of the white fibrous matrix.

The blood-vessels, lymphatics, and nerves, which will be considered later on, are also borne by the connective tissue, and thus brought into close relationship with the gland substance. It is worthy of remark here,

[1] *Quain's Elements of Anatomy*, London, 1876, 8th Ed., p. 394.

that in the pancreas of some mammals, e.g., the cat, the interlobar and interlobular connective tissues often lodge many Pacinian bodies; and it has been observed by BOLL and LAVDOWSKY, especially with regard to the connective tissue of the salivary glands, that isolated groups of migratory cells also obtain in these situations.

The relative amount of connective tissue varies in the glands of different animals; it reaches its maximum development in the human subject, and the division of the organ into lobes and lobules is, therefore, most clearly distinguishable.

THE GLAND SUBSTANCE is composed of two portions; whether these are traceable to a common origin is a question which yet remains to be fully investigated. At all events, their obscure histological relations make it advisable for us to consider them separately.

(i). *The Canalicular System* is formed of numerous minute ducts, which open into larger ones, and these terminate in the principal large duct known as the *canal of* WIRSUNG. In minute structure the ducts vary with their location in the organ, and have hence been divided into distinctive sections. (α). Those which lie in the interlobar connective tissue have been termed *lobar ducts;* they are surrounded by a coat of connective tissue, and KLEIN has observed that in the pancreatic duct, and its larger branches, their walls also possess unstriped muscular fibres. The connective tissue coat is divided from the epithelial lining by a delicate membrana propria. The epithelium itself consists of a single layer of columnar cells, which surround a large lumen; each cell is provided with an oval nucleus situated towards the basal attached portion of the cell, whose protoplasm also exhibits a delicate longitudinal striation. (β). The lobar ducts ramify, and in doing so their branches acquire an intralobular position. In this situation they give rise to the *intralobular ducts;* these resemble the lobar ducts in every essential detail; they are, however, smaller in size, and their outer coat of connective tissue is not so largely developed; their lumina also are relatively narrower, and the protoplasm of their epithelial cells is transparent. (γ). The third section comprises ducts which lie between the intralobular canals and the alveoli. They are continuations of the former, and are much branched and of smaller diameter. In length they vary very considerably; they are sometimes long and tortuous, at other times they are so short that they seem to be entirely wanting. LANGERHANS has stated that they are very long in the pancreas of the rabbit. In minute structure these *intermediary ducts* consist of a basement membrane lined by a layer of endotheloid clear cells, each with a flattened oval nucleus, in which an intranuclear reticulum is very well shown (KLEIN).

(ii). *The Alveolar System* consists of a series of branched convoluted tubules with wavy outlines. In sections they present every variety of outline, the result of cutting through a bundle of tortuous tubuli. The interalveolar connective tissue is very delicate and scanty, but yet sufficient to be easily detected. Each alveolar section shows a basement membrane with a flattened nucleus every here and there; it is composed of branched flattened cell plates connected together by means of processes which

are sometimes filiform and sometimes membranous (HENLE, BOLL). BOLL has observed that some of these processes dip inwards between the epithelial cells of the alveoli and there become amalgamated with the interstitial substance which binds them together.

The epithelial cells are of cylindrical or conical forms, arranged in single columnar layers within the alveolar tubuli; where they are conical their conoid apices project freely into the lumina. It may be observed that between each cell an appreciable amount of clear substance may be detected, and that this interstitial material merges into the matter which fills the lumen; the lumen itself is almost obliterated, as the epithelium occupies nearly the whole of the space within the membrana propria.

The interstitial cement substance of the epithelium has often been mistaken for an ultimate system of canals which were supposed to communicate with the ducts of the canalicular system. Indeed, SAVIOTTI has even figured them from the rabbit, with the utmost clearness as intercellular capillaries, and his figures have been copied into many text-books, some of which state that these canals may be readily injected with a solution of soluble Prussian blue. VON EBNER pointed out that they were merely clefts without walls in the case of the salivary glands, and HERING denied their canalicular character. LATSCHENBERGER came to the same conclusion with regard to the pancreas. There can be no doubt, however, that KLEIN is right in regarding these so-called intercellular passages as merely a clear cement substance, and that the gland alveoli communicate directly with the terminations of the intermediary canalicular system, in a manner which is not yet precisely understood.

Each epithelial cell shows a marked differentiation of its protoplasm into an outer granular layer, and an inner basal portion which seems to be homogeneous. The spherical nucleus is situated in the clear outer portion (*i.e.* that next the basement membrane) near its line of junction with the granular part; it contains a distinct reticular network (KLEIN). The effects of carmine and logwood are useful here; they stain the outer clear band with its contained nucleus very readily, whilst they merely tinge the granular inner stratum in its fresh condition; this is partially due to the existence of fatty particles in the latter. In specimens which have been well hardened the dye acts more equally, and stains the whole cell deeply after prolonged action. The homogeneous outer layer, according to PFLÜGER, consists of a delicate zone of longitudinally disposed fibrillæ; and KLEIN asserts that the granular appearance of the inner part is due to a network of short thick rods, which may be detected by viewing the cell substance obliquely; seen from the top these rods look like so many coarse granules.

The interesting researches of HEIDENHAIN have shown that these intracellular appearances vary with the activity of the organ. Commencing digestion exhausts the granular zone, and the whole cell becomes smaller, but the homogeneous outer band increases slightly in bulk. As digestion goes on, a restitution of the cell contents takes place; the inner granular layer becomes much larger at the expense of the outer homogeneous one, which dwindles down; at the same time the whole cell increases consider-

ably in size. Experiments on the pancreas of the living rabbit revealed to KÜHNE and LEA, that during digestion the outer borders of the cells become more distinctly striated, and the walls of the alveoli are notched,—the result of the increase in bulk of the epithelial cells; whilst in the passive condition the alveoli remain smooth.

Within the lumen of the alveoli branched flattened endotheloid cells with oval nuclei may be detected; these are the *centroacinar cells* of LANGERHANS. Their precise relations to the other structures have not as yet been satisfactorily made out; whether they are a direct continuation of the cells of the intermediary ducts of the canalicular system or not, is still a matter of doubt. In the former case the alveolar epithelium would be included between the membrana propria and the epithelium of the canalicular ducts, and may be looked upon as a modified epithelium specially differentiated for the fulfillment of definite functions in the economy of the gland.

METHODS OF PREPARATION.

The fresh pancreas may be best studied in the smaller Rodents. In the rabbit the glandular alveoli are thinly spread out over a large area of the mesentery, and the pancreatic duct opens considerably below the biliary duct (about a foot below), into the duodenum. In other mammals the gland is so compact that its minute structure can only be studied by means of teasing, and by sections of the fresh or hardened gland.

HARDENING THE PANCREAS may be accomplished by any of the following methods:—

(i.) *Strong Methylated Spirit.*—The fresh pancreas cut into pieces of about half-an-inch square, should be placed in a large quantity of the spirit, which ought to be changed once every day for the first three days, The hardening should then continue in the final change of spirit for three weeks or a month; sections may then be cut.

(ii.) *Absolute Alcohol.*—Forty-eight hours suffices to harden small pieces of fresh pancreas, and fit them for section cutting.

(iii.) *Picric Acid.*—A saturated solution should be used. Very small pieces hardened in this fluid for forty-eight hours, should be transferred to dilute and then to strong alcohol, until they are required. The sections should be stained with picrocarmine, or left unstained, and mounted in Farrants's solution.

(iv.) *Osmic Acid.*—Small pieces should be hardened for two days in a $\frac{1}{8}$th per cent. solution, and the process continued thereafter in alcohol. Sections thus prepared should be mounted in potassium acetate solution, or in Farrants's liquid; they also admit of successful dissociation with needles.

STAINING WITH CARMINE AND LOGWOOD.—Sections taken from material hardened by the two first methods, may be stained with either Carmine or Logwood, and mounted in Canada balsam or dammar solution. See this Journal, pp. 6, 15, 40, 85—86.

THE PANCREAS.

T. S. OF HUMAN PANCREAS.
Injected Carmine.
× 65 diameters.

a Artery, *v.* Vein, *l.* Lumen of Large Duct, *c.* Capillaries of Alveoli, *c'*. Capillaries of Duct.

Etymology.—See Ante., p. 205.

DESCRIPTION.

THE BLOOD-VASCULAR, LYMPHATIC, AND NERVOUS SYSTEMS OF THE PANCREAS.—*The blood-vessels* enter the pancreas from various parts; the arteries proceed to it as branches of the splenic, superior and inferior pancreatico-duodenal rami of the hepatic, and superior mesenteric. Ramifications from these arteries are distributed throughout the gland amidst its connective tissue framework, until repeated division resolves them into a dense but uniform network of capillaries which closely surround the ducts and alveoli. The relations of these vessels to the connective tissue framework and gland-substance of the organ, are well shown in the illustration, which is an exact representation of a section taken from a well-injected specimen. The arterial system passes by means of the capillaries into the venous system, and the blood is conveyed away from the gland by means of the splenic and superior mesenteric veins.

The Lymphatic System.—According to BOLL[1] the lymphatic system of the salivary glands finds expression in a partial circumalveolar cavitary portion and many clefts, which lie between the capillary blood-vessels and the gland substance of the alveoli; from these numerous lymphatics arise, and form a plexus in the interlobular septa of connective tissue. In the pancreas the lymphatics are distributed in a manner which is essentially similar to that just recorded. Large lymph vessels furnished with valves, branch through the interlobar and interlobular connective tissue; these pass into clefts and sinuses, which are lined with endothelial plates, are situated between the intralobular lamellæ of connective tissue, and partially invest the alveoli (KLEIN)[2].

The Nervous System takes its origin from the solar plexus; the fibres in passing through the organ, do so alongside of the blood-vessels and lymphatics. According to PFLÜGER[3] their ultimate fibrils end within the gland-cells themselves, as in the case of the salivary glands, but much doubt has been thrown upon the correctness of his statements by subsequent workers, who have failed to recognise what he has even carefully drawn. Many of the nerves terminate in Pacinian bodies.[4]

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1 *Archiv für mikroskopische Anatomie*, Bonn, Bd. v.
2 *Atlas of Histology*, London, 1880, p. 224.
3 *Archiv für mikroskopische Anatomie*, Bonn, Bd. v; Article *Salivary Glands*, *Stricker's Handbook*.
4 See this Journal, p. 206

The Development of the Pancreas.

The present state of our knowledge of the mode of origin and growth of the pancreas, shows that throughout the *Vertebrata*, with the exception of *Amphioxus* and the *Ascidioida*, its development is very constant. In some cyclostomatous fishes and *Teleostei* it is absent; and in *Petromyzon* and most of the *Teleostei* it is but ill-formed and reduced. In the *Elasmobranchii* and the higher *Vertebrata* it takes its origin as a hollow budding of the hypoblast, nearly opposite to, but somewhat behind, the primitive liver; it assumes the shape of an inverted funnel, the expanded dorsal portion of which grows out into a number of cæcal tubes, and these lie apposed to one another in the midst of the surrounding mesoblastic tissue of the body. The further growth of the diverticula is manifested in their elongation and branching, and whilst these changes are going on, the blood-vessels, lymphatics, and nerves of the organ grow into the connective tissue, and the whole of these structures combine, and result in the production of a solid glandular body, which eventually takes its position in the mesenteric folds at the dorsal part of the digestive tract. The funnel-shaped origin of the organ becomes reduced to a duct which places its canalicular system in communication with the duodenum, and is known as the canal of Wirsung (Balfour).

Methods of Preparation.

The section from which the illustration was taken, was prepared from a specimen obtained out of a fully formed still-born human infant. The carmine mass was injected through the aorta, and the entire circulatory system of the body fully injected; this is the best method of injecting the pancreas. It is obvious that if the organ be injected alone in the adult animal, a perfect injection would be attended with extreme difficulties, on account of the number of blood-vessels which would have to ligatured in order to prevent a great escape of the injecting fluid.

In demonstrating the structure of the pancreas, and of all other glandular bodies, two methods of preparation are requisite, viz., staining, and injecting. The methods of staining are specially adapted to the exhibition of the connective tissue framework, and the epithelial elements of the gland alveoli and ducts; the exact relations of the alveoli to the ducts, is a matter which still requires investigation, and can only be arrived at through the processes of staining the tissues or of examining them in the fresh condition. The method of injection ought only to be applied to the vascular system, and in that case it is advisable to use a permanent colour in a transparent vehicle as the injecting mass. Soluble cold injections are apt to produce illusory effects (especially when they are forced through the pancreatic duct and its canalicular system) by staining the tissues around them to a slight extent. It is easy to understand how such a fluid would enter the alveoli, stain the clear substance of their lumina and even penetrate into the intercellular cement substance and dye it; and there can be no doubt that when Saviotti injected a solution of Brucke's blue through the

system of ducts his results were vitiated in this way, and he made an admirable drawing of canals which do not exist.

In the study of the blood-vessels of the pancreas, a carmine mass should be used, because it is permanent, and when supported in gelatine confines itself to the blood-vessels. The injection should be forced through the aorta, as soon as the body of the animal has reached a uniform temperature of about 40° C. through immersion in warm water. The external appearance of the organ will indicate when it is sufficiently injected. The body should be removed into cold water to permit the gelatine to solidify, and the organ may then be excised and prepared for cutting by being hardened.

CARMINE AND GELATINE MASS.—The preparation invented by Dr. CARTER, of Leamington, is the best for the purpose of injecting blood-vessels with a red material. It is prepared thus :—

Carmine (pure)	60 grains
Liq. ammon. fort. (B. P.)	120 minims.
Glacial acetic acid	86 minims.
Gelatine solution (gelatine 1, water 6 parts)	2 ounces.
Distilled water	1½ ounces.

(A). Dissolve the carmine in the ammonia and water; if necessary the solution may be accelerated by a gentle heat; filter. To the filtrate add 1½ ounces of the hot gelatine solution, and mix it thoroughly. (B). To the remaining ½ ounce of hot gelatine solution add the acetic acid. Pour B into A by dropping whilst stirring the whole fluid. The effect of the acid is to precipitate the carmine, which is then caught in the gelatine, and prevented from forming coarse aggregations, and this prevents a diffusion of the colour through the walls of the capillary blood-vessels.

HARDENING THE INJECTED PANCREAS. 1°. As soon as the injection has solidified within the blood-vessels, the organ may be cut into small pieces, about half-inch square and hardened first in a 50 per cent. solution of rectified spirit, to which one per cent. of hydrochloric acid has been added, then in pure rectified spirit, and finally in absolute alcohol.

2°. Small pieces placed in good methylated spirit which should be changed once a day for the first three days, will be found thoroughly well hardened after about ten days. This method was used in the preparation of the specimen from which the illustration was taken, and is certainly quite as effective as the first mentioned process.

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THE SPLEEN.

T. S. OF HUMAN SPLEEN.
Injected Carmine and Stained with Hæmatoxylin.

a. Endothelial Investment, *b.* Delicate Serous Layer of Connective Tissue with numerous Elastic Networks, *c.* Feltwork of Trabeculæ of Connective Tissue with Blood-vessels and Nerves, *d.* Layer of Unstriped Muscle, *t.* Trabecula of Connective Tissue ensheathing Artery *(ar)*, Vein *(v)*, and Lymphatics *(l)*, *v'*. T.S. of Vein surrounded by Connective Tissue, *v''*. Venous Sinuses of Pulp. The rounded purple elements represent the cells of the pulp and of the Malpighian corpuscles. *m.* Malpighian Corpuscle, *m'*. T.S. of Malpighian Corpuscle with centrally situated Artery, *m''*. Malpighian Corpuscle in which the Artery is seen to terminate in a Capillary Network, m'''. Malpighian Corpuscle in which its Artery is shown passing out into the Pulp Tissue, and anastomosing with the Vessels of the Framework, etc., *ar'*. Arteries of Pulp Tissue.

Etymology.—SPLEEN, *n.* [Lat. *splen*, Gr. σπλήν, the milt or spleen]. *(Anatomy).*—"The spleen is a soft highly vascular and easily distensible organ, of a dark bluish or purplish grey colour. It is situated in the left hypo-chondrium, between the cardiac end of the stomach and the diaphragm. It is the largest of the organs termed ductless glands."[1] The ancients supposed it to be the seat of anger and melancholy.

DESCRIPTION.

ON THE MINUTE STRUCTURE OF THE SPLEEN.—An examination of sections with a low power of the microscope, is sufficient to show that the spleen, like all other glandular bodies, is built up of a framework and a gland substance or parenchyma, and that it differs widely from structures which are obviously concerned in the secretion of elements which are carried away by special ducts and channels, but approaches more nearly to those which are known as ductless glands, more especially the thymus and lymphatic glands.

THE FRAMEWORK consists of a relatively thick capsular investment, from which trabeculæ pass into the substance of the gland, and by ramifying and anastomosing in all directions form a dense network which supports the other elements of the organ.

(i). *The Capsule* may be examined in normal saline solution, from sections of the fresh tissue obtained with the use of a freezing microtome,

[1] QUAIN'S *Elements of Anatomy*, 8th Ed., Vol. ii, p. 397.

as well as in hardened and strained preparations. In either case it will be necessary to use a power of about 300 diameters. The free surface of the capsule if "silvered"[1] will show clearly that it is lined by a layer of endothelial plates, which are essentially similar to those lining the peritoneum. Underneath this comes a band of delicate gelatigenous connective tissue full of interlaced elastic fibrils; this is the serous layer, and it passes by gradual transitions into a much thicker zone of connective tissue, made up of white fibres and their corresponding corpuscles, which produce strands; and these latter unite to form a kind of densely interwoven highly vascular and nervous reticulum.

A large quantity of non-striated muscular fibres, somewhat like those which obtain in the tunica media of blood-vessels, are found in the capsule of the spleen, but their distribution varies in different animals. In most mammals they may be detected as plexuses in the deeper layers under the serosa, and may there be arranged as a superficial transverse and a deep longitudinal layer (KÖLLIKER[2]). They are particularly well developed in the spleen of the horse, pig and dog, and to a less extent in that of the sheep, and ox (BILLROTH[3] KYBER[4]). In the ape, only a thin deeply situated longitudinal layer obtains (KLEIN[5]), and in man these are reduced to thin bundles arranged in plexuses (W. MÜLLER[6]).

(ii). *The Trabeculæ* are inward prolongations of the connective tissue of the capsule. The blood-vessels which enter the organ in company with lymphatics and nerves, are enveloped in the tissue of the capsule which is thus tucked in at this part; but other trabeculæ of various sizes enter the substance of the organ from all parts, as prolongations of its inner coat; they branch repeatedly, anastomose, and thus form a network which becomes continuous with the tissue which enters at the hilum. In form they vary very considerably; some are large and cylindrical, and merge directly into the more delicate tissue to be presently described; others are finer, more band-like, and may terminate by filamentous ends in the substance of the gland.

In histological structure, they consist chiefly of fibrous connective tissue largely intermixed with non-striped muscular fibres longitudinally disposed. KLEIN[7] has observed that in the larger strands the muscular elements form longitudinal bundles, which belong, as it were, to the adventitia of the large blood-vessels which lie within the trabeculæ; he has also detected unstriped muscle cells in even the finest of these.

The great elasticity which the organ possesses in virtue of the high development of these fibrous and muscular elements in its framework is undoubtedly of the highest importance in enabling it to withstand the sudden alterations in size to which it is often subjected.

The intertrabecular portion of the gland is occupied by adenoid connective tissue, arranged in peculiar ways; and admits of a two-fold

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[1] Stained with Silver nitrate, See this Journal, p. 136.
[2] *Handbuch der Gewebelehre des Menschen*, Leipzig, 1867.
[3] *Zeitschrift für Wiss. Zoologie*, Bd. xi.
[4] *Archiv. für Mikroskopische Anatomie*, Bd. vi.
[5] *Atlas of Histology*, London, 1880, p. 423.
[6] *Ueber d. fein. Bau der Milz*, 1865
[7] *Op. cit.*, p. 424.

division into a corpuscular portion, and the pulp. The adenoid tissues of each of these sections merge into each other on the one hand, and into the connective tissue of the trabecular system on the other.

THE GLAND SUBSTANCE of the spleen as has already been noted, finds expression in two groups of tissues which pass into one another, but are yet sufficiently distinct from each other to form a tolerably sharp line of demarcation.

(i). THE CORPUSCULAR ELEMENTS.—In stained sections of the spleen a moderately low power of the microscope (20 or 30 diameters) shows the gland substance in form of a uniformly granular tissue, partitioned off into areas by the trabeculæ, and here and there within these spaces there are portions, usually of sub-circular outlines, which seem to be formed of a more densely granular tissue; these are the so-called *Malpighian corpuscles*. The intervening uniform tissue is the pulp.

In well injected specimens, examined under a power of about 300 diameters, it will be found that these Malpighian corpuscles are formed of a retiform tissue, similar to that which obtains in lymph glands, viz., a honeycombed reticulum, with adnate endotheloid plates, each of which is furnished with a large oval flattened nucleus.[1] At its periphery this connective tissue is in direct continuity with the adenoid tissue which forms the delicate supporting structure of the pulp elements. It is, however, distinguishable from that tissue in being somewhat more densely reticulated. Towards the centre of the corpuscle the meshwork becomes comparatively lax (BUSK and HUXLEY[2]). In the meshes of the reticular network lie the lymphoid cell; each cell possesses one or two large spherical nuclei enveloped in a zone of clear protoplasm.

In the vast majority of instances the outlines of the Malpighian corpuscles are seen to be circular in sections; some of them are oval, and occasionally elongated forms which blend with one another may be detected. Towards the centre, usually in a somewhat eccentric position, the transverse section of an artery may been seen, and this has given rise to the interpretation that the Malpighian bodies are spherical or ovoid masses of adenoid tissue aggregated at intervals upon the arterial twigs of the gland. In reality, however, it has been shown by KYBER[3] and others, that the splenic artery accompanied by the vein, enters the organ at its hilum and continues in the trabeculæ of the framework surrounded by their connective tissue and muscular elements; the vessels in this situation are surrounded by lymphatics, lymph, and interfascicular spaces; but the artery soon leaves the vein, to enter into the intertrabecular areas; here its adventitia become surrounded by a development of dense adenoid tissue cylindrically disposed and varying in amount from place to place. At some parts this adenoid mass is more largely developed on one side of the vessel

[1] In order to observe this adenoid reticulum satisfactorily, it is advisable to cut sections from the fresh spleen, to agitate them well in a test tube of water, and thus to isolate the connective tissue from the other elements. Sections thus treated may be silvered, or otherwise stained, and mounted in any of the ordinary media.

[2] Sydenham Society's translation of KÖLLIKER'S *Histology*.

[3] *Op. cit.*

than on the other; it often becomes equally distributed, and occasionally forms a more or less spherical or ovoid aggregate, especially towards the periphery of the organ. Thus it is that when sections are examined, these cylinders give rise to circular or oval outlines, usually with eccentrically placed arterial sections, but these are sometimes centrally situated. These appearances are obviously dependent upon the direction in which the section has been made.

The central artery of the Malpighian corpuscle may terminate finally within the body itself, by becoming resolved into a network of capillaries, which open into the spaces of the pulp tissue. This may be readily recognised in an injected preparation of the spleen; there it may be seen that the tissue of the Malpighian corpuscle is not pervaded by the injected fluid, as is the case with the pulp tissue, but that on the contrary, it is supplied with a distinct capillary plexus. The artery need not, however, come to an end within the corpuscle; that it does not always do so may often be ascertained, especially towards the periphery of the organ, where the adenoid sheath may be occasionally noticed to cease abruptly, and the artery to emerge and enter on a further, but more limited distribution.

Methods of Preparation.

The best method of injecting the spleen with a gelatine mass, is to operate upon a small animal, and to inject the whole system through the aorta; the spleen should be carefully watched during the process which should be discontinued as soon as it becomes fully distended. Injections through the splenic artery may be resorted to in the case of the larger animals.

The processes employed in the preparation of injected and stained sections, have been fully described at pp. 85, 219, etc.

THE SPLEEN.

T. S. Spleen of Cat, stained Logwood.

× 65 diameters.

c. Capsular Connective Tissue, *p.* Pulp Tissue, *t.* Connective Tissue Trabecula, *v.* Vein. Two Malpighian corpuscles are shown, one of which exhibits the transverse section of an artery.

Etymology.—See this Journal, p. 227.

DESCRIPTION.[1]

(ii). THE PULP TISSUE.—If a small piece of the pulp of a fresh spleen is teased out carefully and examined on a warm stage under a power of about 350 diameters, the characters of its cellular elements may be readily recognised. The dissociation of these elements shows :—(α). Lymphoid cells of many sizes ; some of them possess one, others two or more well marked granular sub-spherical nuclei surrounded by a zone of clear protoplasm ; they all exhibit amœboid movements (COHNHEIM[2]). (β). Cells of similar form, which include in their interior coloured blood corpuscles in various stages of disintegration, from well marked bodies, to mere granular aggregates of a yellowish-brown pigment. (ν) Endotheloid plates usually with one flattened nucleus, but there may be more than one nucleus, and the margins of the plates are produced into band-like or membranous processes. (δ) Spindle-shaped cells of very various forms.

If now a thin, well-hardened and well-stained section is examined under powers of from 3-500 diameters, it will be found that the endotheloid plates (ν) are combined to produce a delicate honey-combed network. In some of these cells, it has been noted by KÖLLIKER, KLEIN,[3] and others, that the nucleus, which is commonly oval and flattened, becomes somewhat modified ; it is beset with many bud-like processes, is often

[1] Continued from p. 230.
[2] *Virchow's Archiv*, Bd. xxxiii, p. 311, *etc.*
[3] *Atlas of Histology*, p. 425.

lobed, and ultimately splits up into a number of small nuclei. These appearances are best seen in the spleen pulp of young animals, such as in man, the dog, pig, guinea-pig, rat, and mouse. The endotheloid cell-plates in virtue of the filamentous, band-like, and membranous processes which they possess, combine to form the reticular meshwork. Their variations in size and position cause corresponding diversities in the dimensions of the intercellular spaces, which range from 8-32μ in diameter. Their substance is generally hyaline, but often contains patches of granular yellowish-brown pigment, and degenerated red blood-corpuscles. These appearances are by no means constant; they are best observed in the spleen of the pig, and in the abnormally congested condition of that organ in the human subject. (KLEIN.)[1]

According to KLEIN[1] the cell plates show spherical or oval corpuscles, which are absolutely identical with the lymphoid corpuscles, attached to them by means of a longer or shorter stalk, or altogether free from them; he looks upon these as the result of a process of gemmation of the endotheloid cells.

The lymphoid cells of the pulp are precisely similar to those of ordinary lymph glands, such as those of the alimentary tract. They lie within the intercellular meshwork of the matrix, somewhat more loosely than their representatives in the Malpighian corpuscles.

Intervening between the lymphoid cells and endotheloid reticulum, spaces exist, which, under normal conditions are filled with blood. The endotheloid plates at intervals become so disposed as to give rise to pseudo-vascular channels, which open into the aforesaid spaces. These pseudo-vascular channels, or *cavernous veins* of BILLROTH, are formed by the peculiar apposition of the endotheloid plates, which become adpressed to form a limitary membranous expansion around a sinus; the processes of the cell-plates pass into the surrounding meshwork, and the sinus is lined by a delicate layer of elastic fibrils. Thus when a superficial view of the the structure is obtained, it appears to be composed of polyhedral cells; a transverse view, however, shows that it is in reality formed by the coalescence of the endotheloid cells to form a membranous coat with occasional stomata, and the elastic fibrillar support is manifested in form of a marginal rim of dots.

The venous sinuses thus constituted form plexuses in the pulp, and these are often arranged in tubular series, as in man and the ape; the intervening tissue thus becomes defined into areas,—the *intervascular tracts* of BILLROTH. The venous sinuses open directly into the veins which are situated within the trabecular connective tissue of the organ. Klein[2] has noticed that they cease to exist in the immediate vicinity of the Malpighian corpuscles, in the case of man and the ape.

The Blood-Vascular System.—The venous system of the spleen commences in the intercellular spaces of the pulp, which open into the venous sinus just described; these, in their turn, empty themselves into

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1 *Op cit.*, p. 426
2 *Op. cit.*, p. 427.

the venous trunks which are situated within the trabecular strands which pervade the whole organ. In addition to this venous system, the pulp possesses arteries; some of these are continuations of the vessels which ramify through the Malpighian corpuscles. It may be noted here, that some of the arteries of the Malpighian corpuscles come to terminations within those bodies, and that preliminary to such ending, they become invested in a layer of concentrically arranged endothcloid plates, between which a few lymphoid corpuscles obtain. Other arteries, which, however, are entirely independent of the vessels of the Malpighian corpuscles, ramify and anastomose in the pulp. KLEIN[1] states that in the cases of man, the ape, and the pig, these vessels become ensheathed in concentrically disposed endotheloid plates, and are to be regarded as small arteries, and not as capillaries with a special *capillary sheath* as suggested by SCHWEIGGER-SEIDEL and others.

Lastly, it has been stated by BILLROTH, GROSSE, SASSE, KYBER, and others, that the intervascular tracts of the pulp, exhibit capillary blood-vessels which connect the capillaries of the Malpighian corpuscles with the venous sinuses of the pulp; but this statement has been altogether denied by W. MÜLLER, FREY, KLEIN, and others, who have shown that the intercommunication of the two systems is effected through the spaces of the honeycombed matrix, which intervenes between the Malpighian corpuscles and the venous sinuses. Our own observations tend to support the latter conclusion.

The peculiarly intimate relationship into which the blood is brought with the cells of the pulp tissue, and the consequent appearances of the cells of that tissue, have led histologists to conclude that one of the functions of the spleen, is to destroy the red blood-corpuscles. The pulp-tissue is also evidently the elaborator of leucocytes; and according to the recent researches of BIZZOZERO and SALVIOLI, it is also the birth-place of coloured blood-corpuscles.

The Lymphatic System.—The researches of TOMSA[2] and KYBER[3] have revealed a capsular plexus of lymphatics, which branch into the substance of the organ, either as closed vessels or in form of clefts; these produce plexuses within the trabeculæ or at their boundaries with the pulp tissue. A perivascular system composed either of tubular vessels or of anastomosing sinuses surrounds the arteries and communicates on the one hand with the trabecular plexuses, and on the other with the adenoid tissue of the Malpighian corpuscles, by means of clefts and lacunæ. The pulp tissue is devoid of lymphatics, except at the margins of the trabeculæ, and KYBER has shown that the perivascular and capsular systems communicate directly with each other in the hilum.

The Nerves of the spleen are derived from the solar plexus, they occur in form of non-medullated fibres near to the arterial branches. W. MÜLLER[4] has stated, that they terminate in the so-called capillary sheaths of SCHWEIGGER-SEIDEL.

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[1] *Op. cit.*, p. 427.
[2] *Sitzungsber. d. k. Akad.*, Wien, Bd. xiv, Abth. I.
[3] *Arch. für mik. Anat.* Bd. viii, p. 568, *et seq.*
[4] *Ueber d. fein. Bau der Milz*, Leipzig, 1865.

Methods of Preparation.

Hardening the Spleen.—If the spleen of a cat or other newly-killed mammal is chosen, pieces about half-an-inch square should be hardened in Müller's fluid for a week, transferred to a solution of chromic acid and spirit for another week, and finally to rectified or good methylated spirit for a third week. Sections should be stained with logwood and mounted in Canada balsam or dammar solution. In the case of the human spleen, it is well to permit the pieces to remain in the chromic acid and spirit solution for two weeks, and then to transfer them to alcohol.

Silver Nitrate Injection.—The blood-vessels should be washed out with distilled water, and thereafter injected with a quarter per cent. solution of silver nitrate. The tissues are then to be hardened in alcohol, and sections exposed to light in the usual way; they may thereafter be stained with logwood. Sections prepared in this manner show the endothelial outlines of the venous sinuses very clearly.

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Note.—It occasionally happens that when organs containing blood (either within their veins, or extravasated) are hardened in alcohol, that crystalline aggregates are formed within its plasma. These are the form of blood-crystals known as *hæmatoidin*. In some of the sections of the cat's spleen issued with this paper, many of these crystals obtain within the venous spaces, sinuses, and vessels, and add very considerably to the value of the preparation.

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THE SALIVARY GLANDS.

V. S. SUBMAXILLARY GLAND OF DOG.

× 500 diameters.

a. Gland Cells of Alveoli, *i.* Cells of Intermediary Duct, shown continuous with Epithelial Cells of Alveolus, *d.* Small Duct, with Epithelium showing well marked Longitudinal Basal Striation, *c.* Interalveolar Connective Tissue, *g.* Crescents of Gianuzzi.

Etymology.—SĂL'I-VA-RY, *a.* [Fr. *salival, salivaire,* Pr. and Sp. *salival,* It. *salivale,* Lat. *salivarius*] Pertaining to saliva; secreting or conveying saliva; as, *salivary* glands; *salivary* ducts.

DESCRIPTION.

In the general arrangement of parts the salivary glands approach most nearly to the pancreas, the minute structure of which has already been fully described[1]. They are essentially of the compound tubular type. The glandular portion of the structure consists of branched tubes of various lengths, they are greatly convoluted, and present wavy outlines (GROT[2]). In direct continuity with these tubular alveoli, canalicular systems arise, and, by their union, finally culminate in the excretory duct of the organ.

The whole of the structures just enumerated, are invested in a framework of fibrous connective tissue.

THE FRAMEWORK consists of a fibrous connective tissue, almost entirely of the gelatigenous variety. The fibres are arranged in lamellæ between which their corresponding corpuscles obtain. The entire organ is surrounded by a moderately thin capsule of this tissue from which inward trabecular processes of various sizes pass, and divide the gland substance into lobes and lobules. The interlobular trabeculæ support the larger vessels and nerves, and also envelop the portion of the canalicular system known as the *lobar ducts;* these ducts, as well as the large excretory duct into which they lead, possess a variable amount of non-striated muscular fibres included in their walls (KLEIN[3]).

[1] See this Journal, pp. 205—208, 217—220.
[2] *Hofmann's Jahresbericht,* 1876, Bd. v, Th. i, p. 312.
[3] *Atlas of Histology,* London, 1880, p. 188.

The lobes are subdivided into lobules by a secondary trabecular system, in which the fibrous elements exhibit a tendency to diminish in definiteness, and become somewhat interlaced. The lobular trabeculæ lodge the ramifications of the vascular system and nerves, they also invest the finer ducts of the canalicular system, which thus come to be *intralobular.*

Each lobule is composed of many tubular branched alveoli, and the lobular connective tissue performs the office of holding these together; the trabeculæ are further sub-divided, and as they thus become interalveolar, their lamellar fibrous character seems to be replaced by a gradual transition into a simple homogeneous tissue, in which connective tissue corpuscles lie imbedded. There can be but little doubt that the layer of the connective tissue, which lies directly in contact with the alveolar gland substance, becomes fused into a membranous form; which, however, is not separable from the interalveolar matrix of the tissue. To this limitary expansion of the connective tissue the term *membrana propria* may be applied. Boll[1] and Lavdowsky[2] have noted that in all parts of the connective tissue, other cells may often be detected; they occur either singly or in small groups, and are the form of connective tissue corpuscles, known as *wandering cells.*

The Gland Substance, admits of a two fold division into a *Canalicular system,* and an *Alveolar system.*

The Canalicular System.—The ultimate radicles of this system,—the *intermediary ducts,* (v. Ebner)[3], arise as direct continuations of the alveolar tubuli, and open into the minute intralobular ducts. They vary in their conformation and structure in different animals; in the submaxillary gland of the dog they are very short, and are lined with a single layer of somewhat cubical transparent cells, with sub-centrally placed spherical nuclei, which merge gradually into polyhedral forms to become identical with the alveolar cells on the one hand (see illustration *i.*), and on the other, pass into columniform cells of the intralobular ducts. In the submaxillary gland of man, the epithelium is reduced to a layer of endotheloid cells, and the duct is often branched before it enters the alveoli (Grot[4].) In every case, the walls of these ducts seem to be composed of a basement membrane strengthened externally by the homogeneous interalveolar matrix, with its included corpuscles. *The basement membrane in this, and every other section of the canalicular system, seems to be the final outspreading of the connective tissue cells which have developed a homogeneous matrix only on their outer sides; this matrix as it becomes more and more strongly formed, differentiates into fibrillæ, and thus arise the fibrous lamellæ of the trabecular and capsular connective tissue.*

According to Nussbaum[5], the action of osmic acid upon the submaxillary gland of the rabbit, shows the cells of the intermediary portion of

[1] *Archiv für mikroskopische Anatomie,* Bd. iv, p. 146.
[2] *Zur fein. Anat. der Spiecheldrüsen, Max Schultze's Arch.,* Bd. xiii, Heft 2.
[3] *Archiv für mikroskopische Anatomie,* Bonn, 1872.
[4] *Loc. cit.*
[5] *Archiv für mikroskopische Anatomie,* 1877.

the duct immediately adjoining the alveolar cells, as distinct from those of any other part, and he concludes from this, that they are specially concerned in the secretion of the salivary ferment. Recently, however, LANGLEY[1] has shown that these statements are incorrect.

The intermediary ducts are thus intralobular in location; they pass into other canals, which, from their positions, have been termed *intralobular*. These *salivary tubes* of PFLÜGER[2], are surrounded by a delicate homogeneous connective tissue which, like that of the intermediary ducts is limited by a membrana propria. The epithelial cells which line these ducts vary in size, and thus produce an irregularity in the outlines of the ducts, which thus come to be wavy; in shape, the epithelial cells are columnar, and they possess somewhat centrally placed spherical nuclei. The protoplasm of the cells exhibits a reticular network, which is developed in a longitudinal direction, especially towards their basal portions; they thus seem to be striated.

By continued ramification, the intralobular ducts reach the trabeculæ which separate the lobules, and become continuous with the next section of the canalicular system, viz., the *lobar ducts*. These are confined to the trabecular system, and by repeated unions form larger and larger canals which ultimately coalesce to produce the principal duct. All the lobar ducts are identical in essential structural details. A transverse section of one of them shows that it possesses a relatively larger lumen than that of an intralobular duct. The epithelial lining consists of a single layer of very regular columnar cells, with spherical nuclei situated towards their periphery. The protoplasm is very distinctly striated in a longitudinal direction, and the nucleus exhibits an intranuclear reticulum (KLEIN)[2]. The epithelium rests upon the limitary expansion of the connective tissue, which now surrounds the duct with a layer of fibrous lamellæ, and exhibits unstriped muscle cells.

The Alveolar System constitutes the true gland substance; its relations to the connective tissue and the canalicular system have already been described. What is noteworthy here, however, is that the connective tissue between the alveoli terminates in the coalescence of a layer of original connective tissue corpuscles, whose processes branch, and are either filamentous or broad and membranous; the branches of contiguous cells coalesce, and a fenestrated membrane is thus produced, which closely invests the alveoli (HEIDENHAIN[3] and others). Some of the processes merge into the superjacent connective tissue, and become involved in its fibrillar matrix, whilst others pass inwards to unite with the intercellular cement substance of the alveoli (BOLL).[4]

The cement substance which binds the cells of the alveoli together is clear and homogeneous, and when stained by means of a soluble coloured injection into the alveoli, appears like so many spaces; they were

[1] *Phil. Trans. Roy. Soc.*, London, 1881.
[2] *Op. cit.*, p. 188.
[3] *Studien des physiol. Instituts zu Breslau*, 1868, Bd. iv.
[4] *Loco citato.*

described as such[1] by SAVIOTTI, LANGERHANS, EWALD, BOLL, CROT, and others, with regard to the pancreas and these glands; v. EBNER[2] stated that they were merely clefts without walls; HERING[3] denies their existence as canals in the salivary glands, and LATSCHENBERGER[4] with regard to the pancreas, whilst KLEIN[5], who is probably right, regards them as filled with a cement substance.

The structural and physiological details of the alveolar cells, led LAVDOWSKY[6] to classify salivary glands into three groups:—

(α) *True Salivary Glands.*—Examples.—The parotid gland of mammals, parts of the submaxillary glands of man and the guinea pig, the orbital and submaxillary glands of the rabbit. The lumen of the alveolus is small; its epithelial cells are somewhat cubical with much rounded angles, and occur in a single layer; their nuclei are peripheral in position and sub-spherical in shape; the protoplasm is granular (due to a dense network) and the nucleus exhibits an intranuclear reticulum (KLEIN[7]).

On stimulation of the sympathetic nerve in the rabbit and dog, the cells of the parotid gland were observed to become very opaque and greatly reduced in size. (HEIDENHAIN, KLEIN[8]).

(β.) *True Mucous Glands.*—Examples.—Submaxillary and obital glands of the dog and cat, sublingual gland of man. The alveolar epithelium is formed of two distinct kinds of cells (see illustration *a* and *g*), which surround a relatively larger lumen than in the true salivary glands. The alveoli themselves are also larger than those of the last named organs.

(i.) The *mucous cells (a)*, (HEIDENHAIN), line the alveolar lumen. When the gland is in a state of activity these cells are seen to be distended, and present shapes which are identical with the goblet cells of mucous membranes, *i.e.* they are of conoid forms terminating in pointed extremities at their proximal fixed ends which are imbricated together and coherent to the processes of the endothelium of the membrana propria. Their protoplasts show an intracellular network the interspaces of which are filled with a clear substance; in the active condition this *mucigen* (so termed by HEIDENHAIN[9]) becomes converted into *mucin*, and through excessive imbibition imparts a globoid aspect to the cells. In the passive state the cell subsides into the condition which has been figured (see the illustration *a*) and its basal portion exhibits a tendency towards a longitudinal striation. Prolonged stimulation of the gland reduces the cells into small densely reticulated granular forms, and resemble the second kind of cells which yet re-

[1] *Ut supra*, p. 207.
[2] *Loco citato.*
[3] *Ueber die Ursachen der hoher Absonderungsdruck in der Glandula submaxillaris, Sitz. d. K. Akad.*, Wien, Bd. lxvi.
[4] *Sitzungsber d. K. Akad.*, Wien, 1872, Bd. lxv.
[5] *Loco citato*, p. 190.
[6] *Loco citato.*
[7] *Loco citato.*
[8] *Loco citato.*
[9] *Pflüger's Archiv*, Bd. xvii.

main to be described. The nuclei of the cells in their normal condition, are closely adherent to the peripheral walls of the cell next to the basement membrane, and appear to be somewhat flattened; a full view of these nuclei shows them to be circular in contour.

(ii.) The *parietal cells*, or *crescents* of GIANUZZI[1] are lunular aggregates of small cells, which obtain at irregular intervals between the mucous cells and the basement membrane of the alveoli. Their protoplasts consist of a very dense reticulum with very little interstitial material (KLEIN), and hence appear to be granular. The cells are polyhedral in shape, and each one possesses a spherical nucleus (ASP)[2].

The stimulation of mucous glands (either by electricity or through chemical reagents), is attended at first by an increase in size of the mucous cells, and the secretion of a viscous fluid; prolonged irritation, however, exhausts the structure, and its mucous cells no longer retain their original aspect; they become small and granular, and look like the parietal cells of the crescents of GIANNUZI. HEIDENHAIN[3] and LAVDOWSKY[3] have asserted that they are destroyed, and that their places are taken by a process of new cell-formation from the parietal areas; but EWALD[4] regards these smaller granular cells as the shrunken remains of the mucous cells, consequent upon exhaustion, and KLEIN[5] is of opinion that such is in reality the case; for, arguing by analogy, he finds that excessive stimulation results in the structural changes which have already been noted, and is accompanied by a watery secretion; *i.e.*, the cells have evidently discharged all their mucin, and have collapsed, and become both morphologically and physiologically like those of true salivary glands. He also states, that in the submaxillary gland of young animals all gradations are met with from "small alveoli with small lumen lined only with small 'granular' cells, and alveoli somewhat larger and lined either partly with mucous cells, partly with granular cells, or altogether with mucous cells to which are applied from place to place groups of 'granular' cells."

γ. *Muco-Salivary Glands.*—Examples.—The submaxillary glands of man and of the guinea pig. In these glands some of the lobules present all the characters of true salivary glands, and are in direct communication with smaller alveoli which are distinctly mucous glands, and *vice-versâ*.

Besides these three forms, BERMANN[6] has observed that in connection with a large branch of WHARTON'S duct in many mammals, he has discovered a compound tubular mucous gland of unique structure.

THE VASCULAR SYSTEM.—The distribution of the blood-vessels, and the lymphatic circulation of the salivary glands, corresponds in all essential particulars with that which obtains in the pancreas[7].

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[1] *Ber. d. K. Sächs. Ges. d. Wiss.*, Sitzung vom Nov. 27, 1865.
[2] *Centralblätt für die medicinisch Wiss.*, 1873, p. 565.
[3] *Loco citato.*
[4] *Beiträge zur Hist. und Physiol. der Speicheldruse des Hundes, Inaug. Dissert.*, Berlin, 1870.
[5] *Atlas of Histology*, London, 1880, p. 191.
[6] *Centralblatt für d. med. Wiss.*, 1877—1878.
[7] *Ut. supra*, p. 217.

THE NERVOUS SYSTEM.—The ultimate distribution of nerves in the salivary glands, is still a question *sub judice*. A plexus of medullated nerve fibres occur in the interlobular connective tissue, and exhibit ganglia here and there; occasionally some of them terminate in Pacinian bodies of a simple kind (KRAUSE)[1]. At other times chains of unipolar ganglionic enlargements occur within the nerves. The researches of PFLÜGER[2] have shown that the medullated fibre which proceeds from the plexus, loses its medullary sheath on reaching the ducts and alveoli; the axial cylinder then pierces the membrana propria of the alveolus, and enters the duct directly; in both cases its fibrils penetrate the epithelial cells, and may even be traced to their nuclei. Other observers have denied PFLUGER'S statements entirely, but they receive support from the investigations of KUPFFER[3], who traced the nerve fibrils to their terminations within the epithelial cells of the salivary glands of the cockroach.

METHODS OF PREPARATION.

The directions given at pp. 208, 218, 219, apply here also.

PFLÜGER'S METHOD OF DISSOCIATION.[4]—Permit the gland, preferably the pancreas of a rabbit, to lie in iodised serum of a light sherry colour for four days, then for two days in about 5 cc. of dilute chromic acid solution (1-50th per cent.) By this means the epithelial cells of the alveoli may be partially digested away, and detached from a wide hyaline sac which they by no means fill; this sac is the membrana propria of the alveolus.

To prepare iodised serum, "add 1 cc. tincture of iodine, and one or two drops of carbolic acid to 100 cc. *fresh* amniotic fluid, and filter[5]." Blood serum may be used where amniotic fluid cannot readily be procured.

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[1] *Zeits. f. rat. Medicin*, 1849, Bd. xx, p. 60.
[2] *Med. Centralblatt*, Nos. 10, 14, 1866; *Stricker's Handbook.*
[3] *Ludwig's Festgabe*, 1875, p. 64.
[4] *The Salivary Glands, Stricker's Manual*, London, 1870, Vol. i. p. 424.
[5] RUTHERFORD, *Outlines of Practical Histology*, London, 1876, 2nd Ed., p. 150.

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THE ALIMENTARY CANAL.

Etymology.—Ăl'i-mĕnt'a-ry, *a.* [Lat. *alimentarius*, Fr. *alimentaire*, from Lat. *alimentum*, from *alere*, to feed, nourish; pertaining to aliment or food].

Can-ăl', *n.* [Fr., Pr., Sp., and Pg., *canal*, It. *canale*, from Lat. *canalis*, originally adj. from *canna*, reed, pipe, a small vessel, Gr. κάννα, or κάννη, reed, and anything made from it, A-S. *canne*, D. *kan*, O. H. Ger and Sw., *kanna*, N. H. Ger. *kanne*, Eng. *can*, a cup or vessel, in modern times made of metal].

Comparative Anatomy.—The term alimentary canal is only strictly applicable to the nutritive system of that section of the animal world known as the *Metazoa*, although it is foreshadowed in some of the higher unicellular organisms amongst the *Protozoa* in the form of an indistinct tract.

Amongst the lowliest organisms, the extempore formation of an alimentary system may be studied in some of the simpler *Amœbæ*; the food particles come into contact with the undifferentiated mass of protoplasm of which their bodies consist, and which in virtue of its tactile properties, exercises a selective faculty in accepting suitable matters and discarding inappropriate substances. When a particle of food comes into contact with the outer wall of the organism, which exists in water, its superficies become raised up on each side of the food, and eventually coalesce around the mass; thus enveloped the food passes into the less dense portion of the body, and is digested; a sort of stomach is thus formed for the time being, and is termed a *food-vacuole*. The undigested portions are evacuated from the body by a similar but inverse process. Thus it appears that any parts of the body-wall are converted into extempore oral and anal regions, and the whole of the protoplast may be looked upon as an alimentary tract. Amongst the higher *Amœbea*, definite areas of the body are restricted to the reception and ejection of food particles.

The ingestion of food amongst the *Protozoa* has not been fully investigated with regard to the forms which develop internal and external hard parts *(e.g., Foraminifera, Radiolaria)*; and in the *Gregarinidæ*, where the animals are dependent upon their parasitic habit, it is supposed that the nutritive processes are provided for through imbibition.

By far the most interesting in this respect amongst the *Protozoa*, are the *Infusoria*; not only do they develop many food vacuoles, but these are generally formed at the base of an oval depression, and excrementitious particles are ejected from a definite area. The oral region sometimes leads into a vestibular space, from which a short permanent channel, the oesophagus, extends within the body as far as its endosarc, where it terminates abruptly *(Vorticella)*. The food, which is directed into the oral cavity, through the agency of its fringing cilia, becomes enveloped

within the endosarc, and forms the so-called food vacuoles; these, in their turn, circulate through a definite tract of the endosarc, and the refuse is expelled into the vestibulum through an extempore anus, which, however, is defined in position. The circulation of the food vacuoles within the almost fluid endosarc may be well seen in *Balantidium*, and in *Paramœcium*, where the movement is very regular and confined to a more limited tract (COHN). In *Nyctotherus*, this limitation becomes still more evident; the food passes from the end of the œsophageal depression straight down the body along an "intestinal tract," to the region of the temporary anus at the other extremity of the body.

Yet further modifications of the alimentary tract have been observed amongst the *Infusoria*. The oral cavity, which is usually ciliated, is sometimes provided with a corneous armature, as in *Dysteria* and *Didinium*, and may entirely give place to a folded membrane in this region, as in *Torquatella* (HUXLEY,[1] BALBIANI, LANKESTER).

The early life-history of the sponges, which has been carefully detailed in the case of *Sycon ciliatum* by METSCHNIKOFF[2], shows that the *Porifera* belong to the *Metozoa*. The impregnation of the ovum results in the development of a *morula*, or mulberry mass of cells; the internal delamination to form a *blastocœle* and its subsequent opening at one end to complete the *gastrula* of HÄCKEL[3] brings the embryo sponge to the threshold of the permanent condition of the *Cœlenterata*,—it is merely a cylindrical body with a simple tubular alimentary canal. The subsequent phases of its life are attended by degenerative changes whereby its original alimentary tract becomes more or less parcelled out into limited areas or channels, which perform the function (through ciliary action) of drawing in water and food through inhalant apertures, which is finally expelled by the large exhalent pore. This, with minor modifications, constitutes the alimentary canal of the *Porifera*.

The *gastrula* then affords a type of a simple animal in which the alimentary tract remains a simple sac, and leads naturally to the permanent form of the cœlenterate *Hydra*; here the alimentary canal is lined by a single layer of endodermal cells,—the derivatives of its hypoblast. Throughout the remainder of the *Cœlenterata* this type remains constant, and is even unchanged in the aproctous *Turbellaria*, as in *Macrostomum*. In the proctuchous *Turbellaria* a slight advance is made in the development of an anus and the sac thus becomes a tube.

The *Rotifera* and *Polyzoa* both present a well developed alimentary canal, in which the tube becomes differentiated into an oral cavity, pharynx, œsophagus, stomach and intestines. Into this region of the body various glands open at different parts of its course, and these become more complex and varied in a progresssion towards the vertebrated types, where they reach their maximum of development.

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1 *On Dysteria, Quarterly Journal of Micros. Science*, London, 1857.

2 *Zur Entwickelungsgeschichte der Kalkschwämme, Zeits. für Wiss. Zoologie*, Bd. xxiv.

3 *Die Gastrula und die Eifurchung der Thiere.*

THE ALIMENTARY CANAL.[1]

The Oral Cavity.

Etymology.—O'RAL, *a.* [Fr. and Sp. *oral*, It. *orale*, from Lat. *os*, *oris*, the mouth, pertaining to the mouth].

Description.

In the human subject, the epidermal layers and *cutis vera* of the skin, the histological anatomy of which has already been described,[2] pass gradually into the mucous membrane and mucosa of the oral cavity through a transitional part,—the red part, seen even when the lips are closely apposed.

The epidermis becomes slightly modified to produce a more delicately formed *stratified squamous epithelium;* the external corneal layer of the epidermis, the cells of which have lost their protoplasmic contents, and are mere periplasts, here assumes a vital aspect in its flattened nucleated scaly cells; and these pass into a zone of prickle-cells, which are identical with those of the *rete mucosum* of the skin, and like them are endowed with the power of proliferation by a similar process, viz.:—the formation of linear series of vacuoles (RUTHERFORD[3]). The deepest layer consists of epithelial cells, which are somewhat columnar in shape, and possess centrally placed oval nuclei; their basal portions are usually branched, and the processes dip down into the subjacent mucosa. The superficial cells of the epithelium in man are usually much flattened, and possess flattened oval nuclei; in most mammals, however, they bear only traces of nuclei, and become fused into a yellowish horny expansion.

Between the epithelium and mucosa, a *basement membrane* exists. It consists of branched endothelial cells, which are doubtless formed by the coalescence of a layer of connective tissue corpuscles to form a membrane, an *endothelial membrane*[4].

The *subepithelial mucosa*, varies in amount in different parts of the oral cavity. It is thickest on the buccal region proper, and the angle of the mouth and lips; it thins away on the soft palate, the palatine arches, and the bottom of the mouth. Its texture becomes firmer, and its depth

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[1] Continued from p. 258.

[2] *Ut supra*, pp. 25—38.

[3] *A Text-Book of Physiology*, Edinburgh, 1880, p. 67.

[4] The term *endothelium*, (Gr. ἔνδον, within, and θηλή, nipple, papilla), is here used in its literal sense. It was first employed by HIS to denote epithelium of mesoblastic origin, but, as only confusion resulted from such an arbitrary use of the term, it gradually came to be restricted to membranes which consist of a single layer of squamous cells, irrespective of their situation, or their embryonic origin. To such membranes the term *endothemal* (Gr. ἔνδον, and τιθέναι to lay, to put) might be applied with some degree of significance, and at the same time only slightly modify the existing nomenclature.

less, over the hard palate and gums; this is due to the tendinous nature of the fibrous tissue which becomes fused to the underlying periosteal membranes. In histological structure, it is composed of a delicate fibrous connective tissue of the gelatigenous variety, arranged in decussating trabeculæ, and is very rich in connective tissue corpuscles, the nuclei of which become deeply stained in tinged sections. Many interfascicular spaces exist amidst this tissue, and serve as channels for the percolation of lymph. Elastic fibrillæ also intertwine amongst the trabeculæ, and may be readily detected by their high refractive indices. Finally, the mucosa is raised into numerous vascular and nervous papillæ over which the basement membrane is reflected, and between which the prickle-cells of the epithelium form the so-called interpapillary processes.

In some mammals, more notably in the ox and sheep, the mucous membrane of the mouth, at its entrance, is beset with many large well-developed papillæ which project high above the general surface, and are covered by a layer of epithelium somewhat after the fashion of the *papillæ filiformes* and *fungiformes* of the tongue; they are absent in the adult human being, but KLEIN[1] has noted their occasional occurrence in the newly-born infant.

The mucosa passes gradually into a more loosely arranged zone in which the bundles of fibrous tissue tend to take on a lamellar disposition; they thus give rise to larger and more definite interfascicular channels, are invaded by clusters of fat cells, are penetrated by the larger trunks of blood-vessels and nerves, and lodge the glandular elements. Bundles of striated muscular fibres also connect this layer with the surrounding fascia and give to it a degree of contractility, whilst its relations to the surrounding organs such as the skin, periosteum, etc., is further effected through modifications of its fibrillar elements into the corresponding portions of those parts. To this illimitable region the term *submucosa* or *submucous tissue* has been applied.

In certain situations (*e.g.*, the soft palate and tonsils), masses of lymphoid tissue are developed, and KLEIN[2] has observed that this adenoid tissue, with its lymph corpuscles, sometimes encroaches on the superjacent epitheliun. through active growth.

Of special interest are the glands which everywhere obtain in the tissues of the oral cavity. They are all of the nature of mucous glands, and as such, belong to the compound tubular type. In all essential details they resemble in miniature, the larger mucous glands which are concerned in the secretion of part of the saliva, and which have already been fully detailed[3]. The largest of these glands are to be found in the soft palate and lower lip. Each gland commences in a duct which opens on to the surface by a funnel-shaped orifice; the duct then passes through the mucosa generally in an oblique direction; on reaching the submucous tissue it subdivides, and each branch continues in a downward course to ultimately dilate into a wider portion termed the *infundibulum*, into which

[1] *Atlas of Histology*, London, 1880, p. 194.
[2] *Op. cit.*, p. 195.
[3] *Ut supra*, p. 246, *et sequentes.*

the branched alveoli of the gland proper open. The superficial epithelium of the soft palate in the human fœtus is usually stratified, and its outermost cells are fringed with cilia; this disappears in the adult, but traces of cilia are sometimes met with at the commencement of the ducts of the mucous glands (KLEIN[1]). In the anurous *Batrachia*, as in *Rana*, the ciliated epithelium persists throughout life, over the entire mucous membrane of the mouth, pharynx, and œsophagus. The stratified cells of the epithelium which surround the orifice of the glandular ducts dip down, in the case of man, into its funnel-shaped depression; in other mammals this is carried to a still further extent, and the attenuated stratified epithelium reaches the deeper portion of the tubule. In both cases, however, it ultimately passes into a layer of columnar cells, each containing a centrally-placed nucleus; the entire protoplasm of the cells exhibits a reticular network, longitudinally disposed in the perinuclear parts. In the region of the submucosa, the lining cells of the duct become somewhat polyhedral and granular, and pass suddenly into the larger mucous cells of the infundibulum. This transition is by no means regular, for KLEIN[2] has noted, and admirably figured, a part of this intermediary duct, in the case of the dog, where the polyhedral cells of one side of the duct pass suddenly into the mucous cells of the infundibulum long before that change is observable on the other side of the duct. The characters of the mucous cells have already been fully detailed[3]; in this place, however, it may be observed that the crescents of GIANUZZI, where they have been observed, are but poorly represented; and that in the early stages of growth the mucous cells are short and granular, possess sub-centrally situated spherical nuclei, and surround but a diminutive lumen, whilst in the fully-developed gland the alveolar cells are large, possess a marked reticular network, flattened basal nuclei, and surround a relatively large lumen. The lumen of the duct, too, is comparatively large.

All portions of the gland are invested in a basement membrane, which shows every here and there a flattened spindle-shaped nucleus, and becomes directly continuous with the sub-epithelial *membrana propria*.

THE BLOOD-VASCULAR SYSTEM.—The submucous tissue lodges the larger vascular twigs; from the arteries branches proceed through the mucosa in an oblique direction, to become resolved into a network of horizontally disposed capillaries in its upper strata, whence looped capillaries arise to supply the papillæ. The efferent vessels originate in the capillary network, and produce a network of their own; thereafter they join the larger veins in the submucosa.

The glands are provided with vessels of their own, which are distributed after the manner of those which supply the pancreas[4] and salivary glands; and afferent and efferent vessels convey blood to and from the striated muscular elements, the adenoid tissue, and fat clusters in a manner characteristic of those structures.

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1 *Op. cit.*, p. 195.
2 *Op. cit.*, p. 196, Pl. xxxii, Fig. xvi.
3 *Ut supra*, pp. 246—247.
4 See this Journal, p. 217.

THE LYMPHATIC SYSTEM.—The researches of TEICHMANN have shown, that the submucous lymphatic vessels send valvate branches into the upper portion of the mucosa, where a superficial plexus of capillaries is formed; from this network, looped diverticula pass into the papillæ. The interfascicular spaces of the connective tissue form irregular lymph-rootlets which merge into definite canals, lined by a layer of connective tissue corpuscles, which thus form walls for these channels; when the corpuscles unite to form a distinct membrane a capillary is produced, and this joins the general lympathic system. The epithelium, moreover, possesses a lympathic system in the vacuoles of its so-called prickle cells.

THE NERVOUS SYSTEM.—The larger nerve trunks which lie in the submucosa ramify to terminate in a plexus of fine fibres in the mucosa; from this, fibrils are given off, and thus arises the fine subepithelial plexus from which still finer branches pass into the epithelial layer. Bodies which simulate the forms of end bulbs and tactile corpuscles, have also been detected in some of the larger papillæ of the lips of certain mammals (KRAUSE, KÖLLIKER, GERLACH).

METHODS OF PREPARATION.

Small pieces of the lips, and portions of the tissues of the oral cavity may be hardened in either of the following solutions:—

(i.) *Chromic Acid and Spirit Mixture.*—This solution should act upon the tissues for about twenty-four hours, and then renewed. At the end of two weeks alcohol should be substituted, and in this they may remain until they are required.

The only drawback to this solution, or to any solution of chromic acid, is, that the striated muscular elements of organs are apt to become dissociated.

(ii.) *Ammonium Bichromate Solution.*—A solution made by dissolving 20 grammes in 1,000 cc. of distilled water, should be used. The tissues should remain in this for about twenty-four hours, and should thereafter be removed to a fresh solution, in which they may remain for about three weeks; they should then be transferred to alcohol until most of the yellow colour is discharged, and retained in alcohol until required.

The sections may be stained with logwood or picrocarmine, and mounted in Canada balsam or Farrants's solution.

THE ALIMENTARY CANAL.[1]

THE TONGUE.

Etymology.—Tongue (tŭng), *n.* [A.-S., L. Ger., and Dan. *tunge*, O. Sax. *tunga*, *tunge*, O. Fries. *tunge*, *tonge*, D. *tong*, Icel. and Sw. *tunga*, Goth. *tuggŏ*, O. H. Ger. *zungă*, N. H. Ger. *zungĕ* ; Ir. and Gael. *teanga*, *teangadh* ; O. Lat. *dingua*, afterward *lingua*.]

Anatomy.—" The tongue is a muscular organ covered with mucous membrane. By its muscular structure it takes part in the processes of mastication and deglutition, and in the articulation of speech, while its mucous membrane is endowed with common and tactile sensibility and is the seat of the sense of taste. The tongue occupies the concavity of the arch of the lower jaw ; posteriorly it is connected with the hyoid bone, and the back part of its upper surface forms the floor of the arch of the fauces ; inferiorly it receives from base to apex the fibres of the genio-glossus muscle, and through the medium of that muscle is attached to the lower jaw."[2]

Explanation of Plates.

Human Tongue.

Papillar Surface with Fauces and Tonsils.

(Sappey.)

1, 2, Circumvallate papillæ ; in front of 2, the *foramen cæcum* ; 3, Fungiform papilla ; 4, Filiform and conical papillæ ; 5, Transverse and oblique ranges ; 6, Mucous glands at the base of the tongue and in the fauces ; 7, Tonsils ; 8, Part of epiglottis ; 2, Median glosso-epiglottidean fold or *frœnum epiglottidis.*

The Tongue.

Papillæ, Glands, etc.

Fig. I.—*Two Filiform Papillæ, one with Epithelium ; the other without* (After Todd and Bowman). *p.* The substance of the papillæ divided at the upper extremities into secondary papillæ; *a.* Artery, *v.* Vein, connected by capillary loops ; *e.* Epithelium, laminated between the papillæ but extended into hair-like processes ; *f.* The extremities of the secondary papillæ.

Fig. II.—*Superficial and Sectional Views of a Fungiform Papilla* (After Todd and Bowman).

[1]Continued from p. 264.

[2]Quain's *Elements of Anatomy*, London, 1876, Vol. ii, p. 325.

A.—The surface of a fungiform papilla partially divested of its epithelium, × 35 diameters, *e.* Epithelium, *p.* Secondary papillæ.

B.—V.S. of a fungiform papilla with its blood-vessels injected. *a.* Artery, *v.* Vein, *c.* Capillary loops of simple papillæ in the neighbourhood, covered by the epithelium; *d.* Capillary loops of the secondary papillæ; *e.* Epithelium.

FIG. III.—*A Circumvallate Papilla from the Human Tongue.* A. With accessory papillæ *c*, its epithelium *a*, and nervous twigs *b*. B. The ridge running round the papilla, with its nerves *b* (TODD and BOWMAN).

FIG. IV.—*Plan of a Lingual Follicle.* *a.* Hollow reduplication of the mucosa with its papillæ; *b.* Lymphoid portion of the walls with several follicles (FREY).

FIG. V.—*Tonsil of an Adult.* *a.* Large excretory passage, *b.* A simple one, *c.* Lymphoid parietal stratum with follicles, *d.* A lobule strongly resembling a lingual crypt; *e.* A superficial, *f*, a deeper mucous gland.

V.S. TONGUE OF DOG.

Circumvallate Papilla × 65 diameters.

The papilla exhibits a median primary division, and each eminence thus formed shows minute secondary papillæ. *v.* The vascular mucosa; the spaces represent sections of capillary vessels. *e.* Stratified squamous epithelium; at the basis of the papilla the taste goblets *t* are shown. *s.* Serous glands which open at the base of the papilla. *d.* Duct of serous gland. *m.* fasciculi of striated muscle cut lengthways. *m'.* T. S. of fasciculi of striated muscle, showing perimysial connective tissue. *f.* Submucosal fat

DESCRIPTION.

Although the mucous membrane of the tongue is in direct continuity with that of the oral cavity, it differs from the latter in several respects. On the dorsum of the tongue, the mucous membrane is raised up into characteristic papillæ which have been termed *filiform* and *fungiform* after their respective shapes, and is comparatively thin and firmly attached to the underlying muscular tissue. At the base of the tongue it becomes thicker, and through its lax arrangement, is thrown into complex definite folds and corrugations.

The epithelium consists of a layer of stratified squamous cells like those of the oral cavity, but since it follows the boundary line of the more marked papillæ on the dorsum, its deepest layer of columniform cells is placed at right angles to the papillar surface. On the lower, the epithelium forms a thinner stratum than on the upper surface of the tongue.

The mucosa is composed of a tissue which is precisely similar to that of the oral cavity. Its upper portion is raised up into two kinds of papillæ. (i.) The *papillæ filiformes*; these may be simple or compound. In the latter instance a common base subdivides into two, three, or more prolonged eminences. Whether simple or compound each primary division gives rise to many secondary projections, and the epithelium covering these may form many

elongated filamentous groups. In most mammals the cells of these filaments become horny and fused together. (ii.) The *papillæ fungiformes* consist of mushroom-like prominences from which numerous minute secondary papillæ project; the whole is covered by a layer of stratified squamous epithelium which obscures the subjacent secondary papillæ. The blood-vessels form a well marked network in the substance of the mucosa, and the general lymphatic system is essentially the same as that in the oral cavity. The variety of fungiform papilla termed *circumvallate* (owing to the development of a large papilla around which the mucous membrane dips down to form a kind of trench), are further distinguished by their rich nervous medullated fibrillæ; they are doubtless intended to supply the organs of taste, which these papillæ support, and according to KRAUSE[1] the distribution of those organs coincides with the ultimate ramifications of the glosso-pharyngeal nerve.

In the root of the tongue, where the mucous membrane is comparatively loosely arranged, the latter is pervaded by many secretory and lymphoid structures.

The secreting apparatus pertains in the form of *mucous* and *serous* glands (v. EBNER[2]). The mucous glands resemble both in structure and position those which obtain in the general oral cavity[3]; they do not occur in the immediate vicinity of the organs of taste, but are found in every other part of the tongue, as at the margins and apex of its dorsum (BLANDIN[4]). In man the epithelium at the commencement of the ducts, is occasionally ciliated (v. EBNER[2]). The serous glands may always be detected in the neighbourhood of the taste organs, and open by funnel-shaped ducts into the trenches which surround the circumvallate papillæ or other papillæ containing taste buds. In structure they are in miniature what the true salivary glands are on a larger scale.[5] Their secretion, too, is watery; they are thus enabled to fulfil the function of rapidly distributing the substances to be tasted over the gustatory organs more efficiently than if they produced a viscous secretion (v. EBNER[2]).

The taste organs were discovered in the *Mammalia*, independently, by LOVEN[6] and SCHWALBE[7]; they were already known to exist in the *Amphibia* as intercalary patches amidst the epithelium of the dorsum and margins of the tongue (Billroth[8], HOYER[9], AXEL KEY[10], ENGELMANN[11].)

In mammals they obtain as rows of ellipsoidal bodies at the base of the circumvallate papillæ, and in some other fungiform papillæ. They are also developed in three or four closely packed rows in the permanent side folds of the *papilla foliata*, situated laterally and at the base of the

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[1] *Göttinger Nachrichten*, 1870.
[2] *Die acin. Drüsen der Zunge*, 1873.
[3] *Ut supra*, pp. 262-263.
[4] *Arch. Gén. de Méd.*, 1823.
[5] *Ut supra*, p. 246.
[6] *Archiv für mikr. Anatomie*, 1867.
[7] *Archiv für mikr. Anatomie*, 1868.
[8] *Archiv für Anat. und Physiol.*, 1858.
[9] *Archiv für Anat. und Physiol.*, 1859.
[10] *Archiv für Anat. und Physiol.*, 1861.
[11] *Zeitschr. für wissen. Zoologie*, 1867.

tongue of man and many other mammals. The papillæ foliatæ are especially conspicuous in the tongue of the rabbit, where they form two lenticular patches of considerable size, one on each side. HOFFMANN has also detected them in certain papillæ on the soft palate, and has also pointed out that single buds occur on the summits of some fungiform and circumvallate papillæ in man,—a fact hitherto denied. Their ellipsoidal form has given rise to the term *taste goblet*, by which they are universally known.

The taste goblets lie embedded in the epithelium of the papillæ in such a manner that their major axes point at right angles to the surface of the mucosa; one pole abuts against that structure, whilst the other reaches the free boundary of the epithelium. The epithelial cells in immediate contact with the goblets become imbricated to produce an investing layer.

Each goblet consists of an outer layer of cells, termed *peripheral* or *tegmental* (SCHWALBE[1], LOVEN[1]); so arranged as to produce the ellipsoidal outline; the cells are elongated, slightly flattened, and fusiform, each with a sub-central flattened or oval nucleus; they are sometimes branched (SCHWALBE[1]). Within the peripheral there occur the *central* or *taste* cells (ENGELMANN[2]); these are delicate fusiform or staff-shaped cells which terminate at both ends in filaments, and possess centrally placed spherical nuclei; their outer processes project slightly beyond the orifice at the free extremity of the goblet formed by the peripheral cells, whilst their inner ends, which are sometimes finely bifid are directed to the subjacent mucosa. Many nerve fibres penetrate to this region, and have been shown by ENGELMANN and HÖNIGSCHMIED to be directly continuous with the taste cells.

The lymphoid structures of the tongue are situated in the mucosa, and from thence extend upwards as diffuse adenoid tissue to the epithelial strata. They occur chiefly at the posterior part of the organ, and may either obtain in the form of nodular aggregates, known as *lymphoid follicles*, or these may become invaginated to produce the so-called *lymphoid recesses* or *crypts*, into which the ducts of secreting glands may also open.

The folds of the oral mucous membrane which form the two prominent bodies know as tonsils, situated one on each side of the fauces, are composed of lymphoid follicles arranged somewhat after the fashion, (but more extended), of those in the mucosa of the tongue. Each tonsil is composed of a mucosa surmounted by a layer of stratified squamous epithelium, as at other parts of oral cavity; its mucosa, however, contains so many closely placed spherical or ovoid masses of adenoid tissue, that it is thrown into many folds, which thus acquire the aspect of numerous crypts placed side by side. The adenoid tissue of the follicles becomes somewhat diffused in their immediate neighbourhood, and often encroaches on the overlying epithelium, which may in this manner ultimately give way to the retiform tissue and its corpuscles. Hence it often happens that the latter find their way into the saliva of the oral cavity and then become the so-called mucous or salivary corpuscles.

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[1] *Op. cit.*
[2] *Stricker's Handbook* 1870.

THE ALIMENTARY CANAL.[1]

The Pharynx.

Etymology.—Phar'ynx (făr'ĭnks), *n.* [Gr. φάρυγξ φάρυγγος, Fr. *pharynx*, It. and Sp. *faringe.*]

Anatomy.—"The pharynx is that part of the alimentary canal which unites the cavities of the mouth and nose to the œsophagus. It extends from the base of the skull to the lower border of the cricoid cartilage, and forms a sac open at the lower end, and imperfect in front, where it presents apertures leading into the nose, mouth, and larynx."[2]

DESCRIPTION.

In minute structure the pharynx admits of a two-fold division into an upper and a lower portion which pass by gradual transitions into one another, and into the respective passages with which it is connected.

The mucous membrane of the upper section, which leads to the respiratory organs, is lined by a stratified layer of columnar epithelial cells, the most superficial of which are ciliated. The mucosa is beset with numerous crypts and folds of adenoid tissue, which is arranged after the manner observed at the root of the tongue and the tonsils, diffuse and in follicles, and led Luschka to term it the "*pharyngeal tonsil*," the pits and crypts of which he describes as lined with ciliated columnar epithelium. Ganghofner,[3] in his paper on the tonsils and *bursa pharyngis* of children, has marked out one portion of the last named structure, to which he has applied the name "*recessus pharyngis medius*," in which ciliated columnar cells alternate with stratified squamous epithelium; the latter is usually developed on the folds of the mucosa, it also obtains in form of small patches every here and there amidst the ciliated epithelium.

The lower and most extensive division of the pharynx is essentially similar in minute structure to the rest of the oral cavity, a detailed description of which has already been given.[4]

The Œsophagus.

Etymology.—Œ-sŏph'a-gŭs (e-sŏf'a-gŭs), *n.* [Gr. οἰσοφάγος, from οἴσω, future of φέρειν, to bear, to carry, and φαγεῖν, to eat.]

Anatomy.—"The *œsophagus* or gullet, the passage leading from the pharynx to the stomach, commences at the cricoid cartilage, opposite the

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[1]Continued from p. 274.

[2]Quain's *Elements of Anatomy*, London, 1876, vol. ii, p. 341.

[3]*Uber d. Tonsilla und Bursa pharyngea, Sitz. d. K. Akad.*, Wien, 1878, Bd. lxxviii.

[4]*Ut supra*, pp. 261—264.

lower border of the fifth cervical vertebra (sixth, BRAUNE), and descending along the front of the spine, passes through the diaphragm opposite the ninth dorsal vertebra, and there ends by opening into the cardiac orifice of the stomach[1]."

EXPLANATION OF PLATE.

T. S. ŒSOPHAGUS OF DOG.

Injected and Stained.

× 65 diameters.

e, Stratified pavement epithelium. *c*, Connective tissue of the mucosa showing numerous small papillæ. *m*, Muscularis mucosæ, composed of many bundles of non-striated muscular fibres. *c'*, Submucous connective tissue, which lodges the mucous glands *g*; these open on to the surface by means of vertical or obliquely-disposed ducts *d*. *d'*, Transverse section of a duct. *m'*, Striped muscular fibres of the circular muscular coat. *a*, Artery, *v*, Vein in the submucous connective tissue.

DESCRIPTION.

The stratified squamous epithelium which characterises the mucous membranes of the oral cavity and lower pharynx of mammals, is continued over that of the œsophagus in those animals, and is especially well developed in man. The underlying mucosa, which also resembles that of the oral cavity in minute structure, is raised up into numerous conical papillæ of variable size, which attain their maximum in the human subject. Beneath the mucosa a layer of non-striped muscular fibres obtains and forms the *muscularis mucosæ*; the fibres are arranged in longitudinal fasciculi of larger and smaller sizes. At the commencement of the œsophagus they are small and separated by a large amount of connective tissue, but they increase in size and number towards the end of the organ, and eventually form a closely set continuous zone. The mucosa and muscularis mucosæ are most largely represented in the *Carnivora;* in the case of the dog the latter is composed of many fine fasciculi connected into a plexus. This is well marked in the illustration where the bundles are shown transversely cut, and very often surround some of the mucous glands which ordinarily lie in the submucosal region.

The submucous tissue contains the mucous glands; in details of structure it is similar to the corresponding layers in the oral cavity. The mucous glands exhibit the same structure and phenomena during normal, stimulated, and exhausted conditions, as the glands of the oral cavity. LANGLEY and SEWALL[2] have pointed out that the œsophageal gland cells are occasionally beset with clumps of highly refractive granules in their peripheral portions; these "*border granules*" as they termed them, are different from the ordinary cell granules; they are very constant in position, and the reaction of osmic acid shows them to be fatty globules. In the human subject they are but sparingly developed, but, in the *Carnivora*

1QUAIN'S *Elements of Anatomy*, London, 1876, vol. II, pp. 343, 344.

2*Proceedings of the Royal Society*, London October, 1879, p. 383; *Journal of Physiology*, 1879, Vol. ii, p. 283.

especially in the dog, the glands are very abundant and well defined. They extend throughout the upper two-thirds, or even more, of the submucous tissue, and in some cases penetrate the region of the mucosa; but in every such case, it may be observed with a high power of the microscope that the gland alveoli are entirely enveloped in a layer of loose connective tissue, similar to that of the submucosa, and is never really embedded in the mucosa proper. The ducts of the mucous glands pass through the muscularis mucosæ and the mucosa in a vertical or oblique direction, and open by narrow mouths on to the surface of the epithelium either between the papillæ or at their summits. The epithelium of the ducts is essentially similar to that described in the ducts of the mucous glands of the oral cavity.

With reference to the glands of *Rana temporaria*, J. N. Langley[1] says:—"I apply the term *simple* tubular to such glands as consist of one tube; when several tubes are given off by one duct, I call the glands *compound* tubular; when the tube or tubes arising from a duct divide, I call the gland a *complex* tubular gland." The œsophageal glands of *Rana temporaria* are complex tubular, those of the dog are of the compound tubular type, as in most other mammals.

The submucous tissue is supported externally by the muscular tunics of the organ. In man, these consist of two coats, an inner circular and an outer longitudinal. The circular exceeds the longitudinal coat in thickness at all parts of the œsophagus, except its upper fourth. The fasciculi of muscles are separated by a fibrous connective tissue, which is a continuation of that of the submucosa. In the upper half of the first fourth, the muscular coats consist of striated fibres; in the second half these are mixed with non-striated fasciculi, and the latter increase gradually amongst the former, until the middle of the œsophagus is reached; after that, striated fibres cease to exist, and the entire tunics are composed of non-striated muscle cells. In other mammals, however, the striated persist amidst the unstriped elements up to the cardiac end of the stomach; the division into a circular and a longitudinal coat, also is less marked, and a third coat is often found, or the entire muscular zone may become spirally arranged.

Outside the muscular coat a thin zone of fibrous connective tissue with its fibres more or less longitudinally disposed, bounds the walls of the œsophagus.

The Blood-Vascular System.—Both in the pharynx and œsophagus the arterial twigs situated in the submucous tissue give off branches, which proceed through the muscularis mucosa to the upper zone of the mucosa, where they form a capillary network; from these loops are given off to the papillæ. From the capillary meshwork in the mucosæ the veinlets convey the blood through the mucosæ and muscularis mucosa to the venous trunks which lie in the submucosa. The muscularis mucosæ the mucous glands, and the external muscular coats possess blood-vessels of their own.

[1] *On the Histology and Physiology of Pepsin forming Glands, Phil. Trans. Roy. Soc.*, London, 1882, p. 664.

THE LYMPHATIC SYSTEM.—The distribution of the lymphatics resembles that which has been described with regard to the oral cavity, our knowledge of which is chiefly due to the investigations of TEICHMANN.[1] In the pharynx and œsophagus KIDD has shown that the lymphatics and lymph sinuses of the mucous glands are connected with the lymphatic system of the submucous tissue.

THE NERVOUS SYSTEM.—The œsophagus is surrounded by a plexus of large nerve trunks, which contain many ganglia (REMAK). According to KLEIN[2], "The nerve-branches that enter the œsophagus form a dense plexus of smaller or larger bundles between the circular and longitudinal layer of the external muscular coat. In these nerve branche we meet with isolated, or chains of ganglion cells (KLEIN); each of these is enclosed in a capsule. The submucous tissue contains another plexus of nerves, connected with the former plexus, and in this also isolated ganglion cells sometimes obtain (KLEIN)."

METHODS OF PREPARATION.

The specimen from which the illustration was taken was injected with a carmine-gelatine mass through the aorta of a freshly killed small dog, and hardened in strong methylated spirit.[3] The œsophagus may also be hardened in chromic acid and spirit solution, but this is liable to dissociate its muscular coats.

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1 *Das Sangadersystem*, 1861.
2 *Atlas of Histology*, London, 1880, p. 203.
3 For a full description of the methods of preparing the injection mass, and the hardening, and staining of sections, see this Journal, pp. 85, 219, etc.

THE ALIMENTARY CANAL.[1]

The Stomach.

Etymology.—Stom'ach (stŭm'ak), *n.* [Lat. *stomachus*, Gr. στόμαχος, from στόμα, a mouth, any outlet or entrance; Fr. and Pr. *estomac*, Sp. and Pg. *estomago*, It. *stomaco*].

Anatomy.—The stomach is that portion of the alimentary canal which commences at the termination of the œsophagus, and places that structure in direct continuity with the duodenal part of the small intestine. Its œsophageal extremity is termed the *cardiac*, and its duodenal, the *pyloric* end.

Explanation of Plates.

THE STOMACH.

Fig. I.—*Cardiac Gland of Bat*, × 420, (Langley). *d.*, columnar epithelium of the surface; *c.*, central cells; *p.*, parietal cells. The upper part of this simple form of gland contains both central and parietal cells and is termed the neck; the lower portion, or fundus, is occupied by only central cells, which exhibit peripheral granules towards the lumen of the gland.

Fig. II.—*Cardiac Gland of Dog*, × 350, (Klein). *d.*, duct or mouth of the gland; *n.*, neck of the gland.

Fig. III.—*Cardiac Gland of Dog*, × 450, (Klein). Portion of the fundus of the gland; *c.*, central cell; *p.*, parietal cell.

V. S. STOMACH OF DOG.

Pyloric End × 65.

The muscular tunics are not shown; *e.*, columnar epithelium covering the folds of the mucosa; *d.*, neck of the gland tubule; m'., mucosa of the region of the necks of the tubuli; *m.*, mucosa of the region of the body of the gland tubuli, showing the latter cut in different directions; *m m.*, muscularis mucosæ; *f.*, lymphoid follicle; *a.*, blood-vessel in submucous region; *s.*, submucosa.

DESCRIPTION.

The mucous membrane of the stomach, like that of the œsophagus, consists of an epithelial layer which becomes continuous with the cells of the gland tubuli; these lie in the mucosa which also supports the external epithelium. Beneath the mucosa comes the muscularis mucosæ, and this overlies the layer of submucous tissue. All these together constitute the mucous membrane, and this is fixed to a thick muscular tunic of non-

[1]Continued from p. 284.

striped elements, which consists of an inner comparatively thick circular coat, and an outer thinner longitudinal layer. Oblique fasciculi also obtain on the inner side of the circular coat (GILLENSKOELD). The submucous connective tissue passes insensibly between the bundles of the external muscular coats to form their perimysial zones, and these, in the same way, coalesce to form the outer limitary boundary of connective tissue, known as the deeper layers of the serous coat,—the peritoneum.

The epithelium of the free surface of the gastric mucous membrane consists of a single layer of columnar cells of much elongated narrow forms. Each cell is provided with a basal oval nucleus imbedded in a densely reticulated protoplasm, the meshes of which become looser towards the upper part of the cell; the peripheric border of the cell is not provided with a striated rim. At intervals some of the cells become changed into mucus-secreting chalice cells, and this is chiefly observable during active digestion when all the cells are secreting mucus (KLEIN[1]). According to WATNEY[2], proliferation of the columnar epithelium both of the free surface and of the ducts, takes place between the smaller fixed ends of the cells, and is manifested in the form of round or oval buds of varying sizes and numbers; and sometimes in small groups. The connective tissue corpuscles beneath the epithelium moreover send out processes which become lost in the cement substance which binds the columnar cells together. WATNEY has also shown that the epithelium is supported by a basement membrane composed of these branched and nucleated endothelial plates.

At the juncture of the œsophagus with the stomach the stratified epithelium of the former ceases abruptly; its lowermost layer of columniform cells alone persists, and eventually forms the gastric epithelium. In its passage into the small intestine, the columnar single layer passes gradually into the somewhat similarly constituted epithelium of that organ.

The mucosa may be resolved into a structure poor in connective tissue fibres, but rich in endotheloid cells; it also possesses a few lymph corpuscles, and in all parts of the stomach, except the transitional areas between that viscus and the œsophagus on the one, and the small intestine on the other hand, is the region in which lie lodged its special glandular structures. In the cardiac end and fundus of the stomach the gland tubes are more or less vertically placed and closely apposed to one another in groups of from four, five, and more. The connective tissue separating these groups varies in amount at different depths; it is much greater towards the surface than at the deeper portion of the ducts. In the pyloric end of the stomach, a gradual transition leads to the formation of somewhat narrow foldlike processes of the mucosa between the ducts of the glands, and endows that region with a villous-like aspect; this becomes the dominant feature of the extreme pyloric end, until, by further differentiation, the true villi of the duodenum are produced. In the deeper part of the pylorus the glands branch, and the mucosa entirely surrounds and lodges them; this restriction of the glands to the mucosa

[1] *Atlas of Histology*, London, 1880, p. 203.

[2] *On the Minute Anatomy of the Alimentary Canal, Phil. Trans. Roy. Soc.*, London, 1876, pp. 451–488.

proper, however, is broken into in the zone which lies between the pylorus and the duodenum, and, in the *Carnivora* especially, it may be observed that the pyloric glands pass through a portion of the structure, at which the underlying muscularis mucosæ becomes discontinuous, to penetrate the submucosal region, and to merge into the glands of *Brunner*, which are confined to the first portion of the duodenum.[1]

The termination of the gland tubes is supported below by an appreciable zone of connective tissue rich in corpuscles; this layer forms the base of the mucosa, and is more distinctly marked in both the small and large intestines than in the stomach.

The muscularis mucosæ forms the boundary of division between the mucosa and the submucosa; it consists of a band of non-striped muscle cells, which varies in thickness at different parts; it is thickest at the summits of the folds of the mucous membrane; this is especially well shown in the neighbourhood of lymphoid follicles in the intestinal tract, and will be alluded to again. The muscularis mucosæ is usually divided into an inner circular and an outer longitudinal layer; occasionally a third inner oblique or longitudinal layer obtains. WATNEY[2] has pointed out that many fasciculi penetrate into the mucosa and pass into the tissue between the gland tubuli; some of these become attached to the basement membrane of the epithelium, others maintain a horizontal course. In the stomach of the cat, ZEISSL has shown that a moderately thick zone of elastic fibres forms a membrane on the outer side of the mucosa, and is penetrated from beneath by muscle fibres, blood-vessels, etc.

The submucous tissue, like that of the œsophagus, consists of a loosely arranged fibrous meshwork with its corresponding corpuscles. It lodges the twigs of the blood-vessels, lymphatics, and nerves which supply the mucous membrane generally.

The glands which are concerned with the secretion of the gastric juice have already been localised. They are distinguished into two varieties which, in their typical forms, differ from one another both morphologically and physiologically; nevertheless they pass by gradual transitions into each other. It is only recently that an attempt has been made to assign to these glands, names which, at least, are free from objection. To J. N. LANGLEY[3] belongs the honour of introducing a rational nomenclature; he says:—

"I propose to use the term *oxyntic* glands, (ὀξύνειν, to make sour, to acidulate), for those glands in the stomach which are differently called by different observers 'fundus,' 'peptic,' or 'rennet' glands. It is only after great hesitation that I venture to employ a new term, but without a new term I find myself reduced to circumlocution or inaccuracy. That the present nomenclature is unsatisfactory scarcely needs to be pointed out. In the rat there are no glands in the fundus of the stomach; in the rabbit the glands of the fundus proper differ in some important points from those of the greater curvature, yet both are called fundus glands. The terms peptic and rennet glands are inappropriate, since the pyloric glands also secrete the peptic and rennet ferments. The terms 'simple' and 'compound' glands suggested by EBSTEIN[4] are applicable only to the gastric glands of mammals,

[1] This is well figured by NOBLE SMITH, in KLEIN'S *Atlas of Histology*, London, 1880, Plate xxxiv, Fig. iii.

[2] *Loco citato.*

[3] *Philosophical Transactions of the Royal Society*, London, 1881, pp. 665-666.

[4] *Max Schultze's Archiv*, 1870, Bd. vi, s. 538.

for it is only in mammals that compound glands, i. e , glands possessing both border and chief cells occur."

"The one characteristic point of the 'fundus' 'peptic' or 'rennet' glands in all animals, is the secretion of an acid fluid. The characteristic is suggested by the word *oxyntic.*"

The Oxyntic Glands.—Each oxyntic gland admits of a rough division into three parts,—the *duct*, the *tube* or *neck*, and the *body* or *fundus.* They were first recognised by HEIDENHAIN[1], but afterwards more fully described by PARTSCH[2].

One duct generally serves for the outlet of two or three tubes. The cells of the duct resemble, in all essential details, those of the free surface of the mucous membrane; they surround a comparatively large lumen in most mammals. The lumen of the neck is extremely narrow and can thus be readily distinguished, even in transverse sections, from that of the short duct: it is directly continuous with the lumen of the fundus which at its lower extremity becomes somewhat wider.

The cells which enter into the formation of the oxyntic glands are of two kinds; both of these lie within the basement membrane which bounds the tubuli. The whole of the neck and fundus is lined by a single row of columnar cells, which are directly continuous with the cells of the duct, but they differ from the latter in size; they are smaller, denser, somewhat cubical, and possessed of small oval nuclei in the neck; as these pass into the cells of the fundus, they assume a more distinctly columniform shape, and are longer and more transparent than their representatives in the neck. HEIDENHAIN[3] termed them the *chief* cells, ROLLETT[4] called them *adelomorphous;* they have also been termed *central* cells, since they surround the lumen of the tubuli. According to KLEIN[5], the granular aspect of these cells and their nuclei, is due to a reticulum within them, the meshes of which contain a hyaline interstitial substance of variable quantity; the more granular the cell, the closer is this reticulum.

But besides these cells there are others, which, under the name of *peptic* cells, were long considered to be the only cells of the gastric tubuli. They were first shown by HEIDENHAIN[3] to lie between the chief cells and the basement membrane; he, therefore, termed them *parietal* cells—the *delomorphous* cells of ROLLETT, *oxyntic* cells of LANGLEY, and *border* cells of other writers. These cells are somewhat oval or spherical in outlines, and slightly compressed vertically; they are much more easily detected than the chief cells, on account of their opaque, granular substance, and its ready imbibition of staining reagents; each cell possesses a clear, oval nucleus, and, in consequence of its shape and position, often causes the membrana propria to bulge out, and thus gives rise to the sinuous outline of the gland tubes in the dog and most other mammals; in the porpoise and the pig the cells are situated in special recesses formed by the protrusion of the basement membrane, and communicate with the rest of the tubule by means of

[1] *Max Schultze's Archiv*, 1870, Bd. vi, s. 394.
[2] *Max Schultze's Archiv*, 1877, Bd. xiv, s. 179.
[3] *Loco citato.*
[4] *Grdz Unters*, 1871.
[5] *Atlas of Histology*, 1880, p. 204.

narrow orifices. In the proventriculus of birds, this is carried to a greater extent, and the parietal cells occur in secondary tubules; these lead into the principal tubule, which contains only chief cells. In frogs, only parietal cells are found in the oxyntic glands, but this is compensated fo by the occurrence of glands with chief cells in the œsophagus. KLEIN has shown that the densely granular aspect of these cells is due to intra cellular and intranuclear networks.

In location, the parietal cells are of commoner occurrence towards the neck of the tubule; they are more sparingly developed in the fundus, and cease altogether at the duct. Indeed, this is so constant amongst the higher *Mammalia*, that KLEIN has stated that it is possible to recognize whether the tubule is cut transversely at the neck or fundus, when taken together with the evidence furnished by the size of the lumen and the quantity of intertubular connective tissue.

The gland tubes are arranged somewhat vertically side by side, they may be straight or wavy, and their ends are usually curved to one side like a hook; but it depends very largely upon the animal what these proportions and shapes shall be, for they are determined by the form and position of the cellular elements which build up the gland tubuli, as has already been shown.

As the pyloric end of the stomach is approached, the glands gradually become altered in characters until they merge into the form typically known as the *pyloric gland.*

The Pyloric Glands.—As in the oxyntic glands, these structures admit of a three-fold separation into *duct*, *neck*, and *fundus* portions. The duct is relatively long, it usually amounts to about half the length of the entire tube, its epithelium is similar to that of the free surface of the stomach. Into the duct, from two to three tubes open by very short necks, each with a minute lumen; they widen out to form the fundus which is generally divided into two or three wavy branches. The epithelial lining of the neck and body is a continuation of that of the duct; its cells, however, are shorter and denser, those of the neck being almost cubical, whilst the fundus cells are more transparent and of columnar form. In minute structure they resemble the chief cells of the oxyntic glands, *i.e.*, they are composed of a delicate reticular substance.

The basement membrane of all the gastric glands is composed of a network of endotheloid cells with branched processes; some of these are fused with the subjacent mucosa, whilst others extend into the epithelium, there to become absorbed in the interstitial cement substance of its cells.

During active secretion the chief cells of the oxyntic glands show a separation of granular elements towards their peripheral portions next to the lumen; it has been shown by LANGLEY[1] that some of these granules become discharged with the secretion, and that after digestion they gradually retire, so as to cause the cells to reassume their uniform granular aspect, which they exhibit during rest. This is well seen in the illustration of the cardiac (oxyntic) gland of the bat. According to HEIDENHAIN[1] both the chief and the parietal cells become bulkier during digestion, and on the cessation of active secretion may shrink to even

[1] *Loco citato.*

less than their original sizes; these changes are said to occur later in the parietal than in the chief cells. In the pyloric glands, the changes which occur in the cells during the active and passive states of the organ, are strictly comparable to those which take place in the chief cells of the oxyntic glands.

The mucosa of the stomach, more particularly at its pyloric end, is often invaded by lymphoid follicles; these are met with more frequently in the organs of young subjects; they are confined to the mucosa and fade off gradually into its tissues.

THE BLOOD-VASCULAR SYSTEM resembles that of the œsophagus, except in the mucosal region. The capillary network of the mucosa is prolonged into an elongated meshwork of capillaries which envelop the tubuli, and give rise to a dense horizontal plexus immediately beneath the epithelium; from this the venous rootlets arise.

THE LYMPHATIC SYSTEM.—The researches of LOVÉN[1] have shown that a dense canalicular system surrounds the tubuli and blood-vessels of the mucosa around the bodies of the gland tubes; from this, numerous lymphatics proceed to a deep plexus of larger vessels in the submucosa (TEICHMANN[2]). Other lymphatics, which take a longitudinal course between the gland tubes, open into the plexus around the bodies of those structures, and after freely anastomising, extend towards the surface, where they terminate in loops or saccular diverticula. Very often the lymphatics invaginate portions of the gland tubes.

METHODS OF PREPARATION.

THE NERVOUS SYSTEM.—The nerves, which are large, are derived from both branches of the pneumo-gastric, the right branch descends upon the back and the left branch on the front of the stomach. Branches from the sympathetic system also proceed to the stomach from the solar plexus. The nerve trunks of both systems carry minute ganglia (REMAK). The branches enter the muscular coat and extend between its layers, as the plexus of AUERBACH, which contains many ganglion cells from apolar to multipolar forms. From this stratum proceed branches into the submucosa, where they form the plexus of MEISSNER, which includes minute unipolar and bipolar ganglion cells. According to RABE, a rich plexus of nerves surrounds the gastric glands of the horse, and some of them end in peculiar doubly nucleated spindle cells.

The methods of hardening, and of cutting, and staining sections of the stomach have been fully detailed with regard to other parts of the alimentary canal. (pp. 264—284).

[1] *Nord. Med. Ark.* Bd. v, 1873.
[2] *Das Saugadersystem*, 1861.

THE ALIMENTARY CANAL[1].

The Small Intestine.

Etymology.—In-tĕs'tĭne, *n.*; *pl.* In-tĕs'tĭnes, [Lat. *intestinus*, from *intus*, on the inside, within; It. and Sp. *intestino*, Fr. *intestin*].

Anatomy.—That portion of the alimentary tract which extends from the distal (pyloric) end of the stomach to terminate in an external orifice, —the *anus*. It is divided, in the higher animals, into two chief portions which differ from each other both in structure and functions, and are known as the *small* and the *large* intestines. The small intestine is further subdivided into three sections which pass by gradations into one another, and are termed respectively, the *duodenum*,[2] *jejunum*[3] and *ileum*[4] The ileum opens by a valvate aperture (the *ileo-cæcal*, or *ileo-colic* valve.) into the first portion *(cæcum* or *colon)* of the large intestine.

Explanation of Plate.

T. S. Duodenum of Dog.

× 25 diameters.

v., villus; *c*, crypt of Lieberkühn; *mm.*, muscularis mucosæ; *s.*, submucosa, containing the gland of Brunner; *d.*, duct of one of the glands; *s'.*, lower submucosa devoid of glands, and of very loose texture; *m'.*, circular muscular coat., *m''*, longitudinal muscular coat; *a.*, plexus myentericus of Auerbach.

DESCRIPTION.

The structures which enter into the formation of the small intestine, may be considered under the following heads:—the *mucous membrane*, the *muscular coat*, and the *serous coat*, and these are richly supplied with vessels and nerves. The mucous membrane of the small intestine is raised up into numerous permanent folds which extend inwards in a direction at right angles to the length of the tube, and thus form a series of dissepiments of variable size, in addition to the effaceable rugæ which beset its walls. These are the valves of Kerkring known as *valvulæ conniventes*; they serve to increase the surface of the mucous membrane,

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[1]Continued from p. 292.

[2]N. Lat., from *duodeni*, twelve each; so termed because its length is about twelve fingers' breadth.

[3]Lat. *jejunus*, empty, dry; originally so named because it was supposed to be always empty after death.

[4]N. Lat. *iliacus*, from *ilia*, groin, flank, small intestines, N. Lat. *ileum*,, *ileon*, the last portion of the small intestines, from Gr. εἰλειν, εἰλεῖν, to roll, to twist up.

an important factor in the function it performs as an absorbing and secreting organ. The valvulæ conniventes commence at a short distance from the pyloric end of the stomach, and attain their maximum development near the orifice of the bile and pancreatic ducts within the duodenum; they continue to be well marked until the lower half of the jejunum is reached, and thereafter diminish both in size and number towards the end of the ileum, where they cease altogether.

The mucous membrane, like that of the stomach, is made up of four distinct layers:—1°, the *epithelium*; 2°, the *mucosæ*; 3°, the *muscularis mucosæ*; 4°, the *submucosa*.

The *epithelium* may be taken as the outward expression of the glandular elements which are lodged within the other layers. Indeed the whole intestinal tract, may be looked upon as a huge tubular gland into which secondary minute tubules of various forms open and discharge their contents. In addition to the structures which endow the intestines with a secretory function, provision is made for its action as an absorbent organ, whereby formed material can find its way into the nutrient vascular systems of the body.

The chief characteristic of the small intestine lies in the peculiar disposition of its mucosa. It has already been stated that the valvulæ conniventes seem to be designed to produce a maximum secreting and absorbing surface, but this surface is immeasurably increased by the development of numerous minute elongated *villi* or processes of the mucosa; the external epithelium which stands vertically to the surface, is thus thrown into an infinitude of valleculæ which have been described as glandular structures under the name of *crypts* of LIEBERKÜHN. True glands, *i.e.* those which each exhibit a neck, duct, and body, do find a place in the small intestine, but they are altogether subordinate and obtain only in its duodenal portion; they are known as the glands of BRUNNER, and from the fact that they pass by gradations into the pyloric glands of the stomach[1], and are similarly constructed though more deeply seated, it is possible that they exercise a secretory function analogous to that of the pyloric glands.

In form, the villi vary in different parts of the intestine, and in different animals; in the hedgehog they are lamelliform; in man, the dog, and cat, they are long slender and cylindrical; they are longer in the duodenum than in the jejunum and ileum; in the mouse they are short and conical.

The superficial epithelium consists of a single layer of beautiful columnar cells, each provided with an oval nucleus at its proximal fixed end. Both nucleus and cell substance consist of a reticulum of denser matter, the interstices of which are filled with a hyaline substance. The distal free border of each cell is provided with a striated rim, the markings of which are due to prolongations of the intracellular network. Every here and there the striated border is lost, and the body of the cell assumes a globular shape, from which the mucus now

1 *Ut supra*, p. 289.

escapes through the open free surface, and the nucleus retires to the other extremity, which becomes attenuated through the bulging out of the other part (KLEIN[1]). It has been stated by THANHOFFER[2] that the fixed ends of the epithelial cells in *Rana* terminate in two processes, one of which is connected with a nerve, whilst the other passes to the tissue of the villus; but this certainly does not obtain amongst mammals; the ends of the cells are generally truncated, and at most exhibit only slight indentations (SCHÄFER[3]). The epithelial cells are held together by a clear homogeneous cement substance, which is in direct continuity with the adenoid reticulum of the mucosa below, and very often lymph corpuscles may be discovered between the columnar cells (WATNEY[4]). Where the upper portion of the mucosa is invaded by lymphoid follicles, the superjacent epithelium very often becomes altered in character; this is manifested chiefly in a loss of the columnar shape of the cells, and their subsequent degeneration into polyhedral forms, in which the nucleus becomes conspicuous.

The precise method by means of which nutrient matter finds its way into the central lacteals of the villi, is a matter which still remains undecided. One class of observers assert that the epithelial cells are themselves the active agents in this process, and that they absorb the formed material or chyle and then discharge it into the tissue of the villi, whence it is taken up by the central lacteals and thus conveyed to other parts of the bodily economy. This hypothesis is based on the assumption that there is a direct continuity between the cells of the epithelium and the tissue of the mucosa, an assertion which has been denied by most observers, and certainly does not hold good for the *Mammalia*. The other view, which is in accordance with observed facts, is that advocated by WATNEY, KLEIN, and others. The interstitial cement substance of the epithelium is in direct continuity with the mucosa; the presence of lymph corpuscles between the epithelial cells, would alone suffice to evidence this. In the fresh state the intercellular cement is easily permeable by fluids, and it may readily be imagined that the chyle thus finds its way into the mucosa. As the flow of formed material within the absorbent vessels is centripetal, the chyle would tend to pass towards the canalicular system and be taken up by it through its delicate walls.

The epithelium rests upon a *basement membrane*, which consists of a single layer of endothelial plates, provided with processes which extend in all directions (DEBOVE[5]).

In intimate structure the *mucosa* is essentially similar to that of the other parts of the alimentary canal. It is reduced to a comparatively narrow zone, from which elongated processes the villi extend vertically outwards. The free surface of these villi is covered with a basement membrane, which in its turn is surmounted by the epithelial layer. The spaces between the villi thus appear like glands, and were first described as such by LIEBERKÜHN[6].

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1 *Atlas of Histology*, London, 1880, p. 13.
Pflüger's Archiv, 1873, Bd. viii.
2 *Quain's Elements of Anatomy*, London, 1882, vol. ii, p. 603.
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4 *Phil. Trans. Roy. Soc.*, London, 1876.
5 *Comptes Rendus*, Paris, 1872.
6 *De Fabrica et Actione Villorum*, Amstel, 1745.

The mucosa rests upon a band of non-striated muscular fibres;—the *muscularis mucosæ*. This consists of an inner thin circular, and an outer delicate longitudinal portion; but the circular coat may sometimes be wanting, and the longitudinal coat is very often so reduced, that it can barely be detected with a high power, which reveals the presence of a few of its elements. Offshoots spring from this layer and invade the substance of the mucosa and its villous surface.

The *submucosa* is, like that of the stomach, composed of trabeculæ of loosely arranged fibrous connective tissue; it lodges the arterial and venous trunks, lymphatic vessels, and fatty tissue. It is the seat of the glands of BRUNNER, and of solitary or agminated lymphoid follicles; the latter produce the structures termed *Peyer's patches*.

The glands of BRUNNER resemble the pyloric glands of the stomach in everything except their position; they are more deeply seated, and, as a consequence, their ducts which open between the so-called *crypts* of LIEBERKÜHN, are longer. The columnar cells which line the gland tube are separated from one another by minute *capillary channels* (SCHWALBE[1]). The glands themselves are compound tubular; in the dog they are collected in largest numbers towards the end of the duodenum, where they form a comparatively wide zone in the submucosa; at the commencement of the duodenum they are scantily represented, and may be detected in the jejunum and even in the ileum. In man they are confined to the first part of the duodenum. Muscular fibres, derived from the muscularis mucosæ, are associated with the periglandular connective tissue (VERSON[2]).

The *external muscular coat* consists of a very wide inner circular, and a narrow longitudinal portion; these are separated from each other by a nervous layer, the *plexus myentericus* of AUERBACH[3],

The blood vascular, lymphatic, and nervous systems will be described with those of the large intestine.

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[1] *Archiv für mikroskopische Anatomie*, 1871, Bd viii.
[2] *Stricker's Handbook*, 1871.
[3] *Virchow's Archiv*, Bd. xxxiii.

THE ALIMENTARY CANAL.[1]

The Large Intestine.

Etymology.—See this Journal p. 299. *Anatomy.*—The large intestine is divided by anatomists into three chief portions. The first part termed the *cæcum*[2], forms a wide but very short tube in man; it terminates blindly, in an extremely attenuated hollow prolongation, which, from its shape, has been called the *vermiform appendix*; this structure is confined to man, the higher apes, and the wombat, but it reappears in a somewhat less pronounced though larger form in the rabbit and its congeners. The *colon*[3], or second portion, commences at the cæcum opposite the ileo-cæcal valve, and ends in an S-shaped part, its sigmoid flexure, to enter the *rectum*[4], or third and final section of the large intestine.

Explanation of Plate.

T.S. Large Intestine of Dog.

× 25 diameters.

c., crypt of Lieberkühn cut vertically; *c'.*, crypt of Lieberkühn cut transversely; *mm.*, muscularis mucosæ shown raised up on each side of a solitary lymphoid follicle *l.*; it is discontinuous at the summit of the follicle; *s.*, submucosa; *m'.*, circular muscular coat; *m''.*, longitudinal muscular coat; *a.*, plexus myentericus of Auerbach.

DESCRIPTION.

The membranes of the small are in direct continuity with those of the large intestine; they are essentially similar, but present certain differences in structure (observable in progression from the proximal to the distal or anal extremity) which arise as adaptations to the varying functions of each section. Thus the villi of the small are altogether absent from the mucous membrane of the large intestine, and, in consequence of this, its vascular systems become considerably modified towards their periphery, and thereby their secreting and absorbent functions are modified.

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[1] Continued from p. 302.

[2] Lat. *cæcus*, blind, concealed; Ger. *blinddarm.*

[3] Lat. *colon*, *colum*; Gr. κωλον, limb, member, especially the largest of the intestines.

[4] Lat. *rectus*, straight; so termed by the older anatomists who described it first in the lower orders of the *Mammalia.* In man the rectum is far from being straight.

Although villi do not pertain to the large intestine, minute papillary growths of the mucosa may sometimes obtain, as in the colon of the rabbit. These papillæ, however, are not strictly comparable to the villi, since they are surmounted by the surface epithelium with its numerous crypts of LIEBERKÜHN, as in the rest of the large intestine.

According to KLOSE[1] the epithelial cells of the mucous membrane assume the appearance of ordinary columnar cells after active secretion, both on the surface and within the crypts of LIEBERKÜHN; under normal conditions the cells of crypts are more mucoid than those of the surface. In the rabbit all these cells are distended with mucus; in the dog only alternate cells are so affected. In all other respects the epithelium is similar to that of the small intestine. In intimate structure, the mucosa resembles that of the small intestine.

The muscularis mucosæ is usually disposed in an inner circular and an outer longitudinal layer of non-striped cells, although either stratum may be absent. Of interest are the minute offshooting fasciculi which may sometimes be seen to leave the inner zone, and to ascend between the crypts of LIEBERKÜHN; in the colon of the rabbit, these muscle cells penetrate the minute papillæ which occur in that structure, and on reaching their apices are inserted in the basement membrane underlying the epithelium (WATNEY[2]).

The submucosa is like that of the small intestine; if a distinction can be drawn between them, that of the large intestine may be said to possess a relatively greater amount of adipose tissue. This portion of the structure lodges the lymphoid glands, which generally pertain as solitary follicles, and are commonly larger than those of the small intestine. One of these follicles is depicted in the illustration, and shows in a typical manner the relation which usually subsists between it and the circumjacent tissues. The follicle is shown as an eminence projecting through the mucosa; its summit has reached the epithelial layer, and induced a degeneration of the crypts of LIEBERKÜHN and boundary epithelium; in the mucosal region its body passes gradually into the adenoid reticulum of that structure. The muscularis mucosæ also is raised up on each side of the follicle, and the growth of the latter has occasioned a breach through which its summit protrudes into the mucosa. In the pig, and occasionally in man and the dog, the structures which overlie the follicle are drawn down towards its more deeply seated summit; there thus results a superficial pit, instead of an eminence, into which the mucosa and epithelium are drawn down. Where many follicles are aggregated a PEYER'S patch results; in the cæcum of the rabbit these are well shown, and the vermiform appendix of man and other animals, contains many such follicles compactly disposed. In a PEYER'S patch the follicles are precisely similar to the one already described; their proximity, to each other, causes their bodies to become confluent whilst their summits and bases remain distinct from one another; these phenomena may be readily observed in the cæcum of the rabbit, the lower part of the ileum in the dog or cat, or the processus vermiformis where that organ obtains.

[1] *Inaug. Dissert.*, Breslau, 1880.
[2] *Phil. Trans., Royal Society*, London, 1876.

The muscular tunic of the large intestine consists of an inner circular and an outer longitudinal coat; neither of these layers are regularly disposed. The circular coat forms groups in the septa of the sacculi of the colon, whilst the longitudinal coat is parcelled out into strips (the so-called ligaments), which are shorter than the entire length of the intestine; this causes the sacculation of that viscus, for when the longitudinal bands are removed by dissection the saccules disappear. The rectum forms an exception to what has been stated, in the possession of a well-developed coat of uniform thickness, its circular layer is very thick; its mucosa also is largely represented.

The serous coat of both the small and the large intestines, is continuous with the two layers of the mesentery which are reflected over the intestinal tubes at all parts except a small linear portion where the vessels and nerves enter, and which has teen termed the *attached* or *mesenteric border*. It is essentially a part of the peritoneum. Along the colon and rectum it gives rise to numerous small projections which include an amount of fatty tissue, and are known as *appendices epiplöicæ*.

THE BLOOD-VASCULAR SYSTEM is arranged in both the small and large intestines in several systems, which agree with the distribution of those structures in the stomach, in all essential details. Each portion is provided with its own vessels; thus separate systems supply the mucous membrane proper, the lymphoid follicles, BRUNNER'S glands, the muscularis mucosæ, the external muscular coat, the fatty tissue of the submucosa, and the serous coat.

Within the submucosa are situated the larger arterial and venous twigs, from which the contained and superjacent tissues are supplied. The capillaries and veinlets of the external muscular coat also pass to the larger vessels of the submucosa; they are arranged in an elongated meshwork of minute vessels, as in all non-striated muscular tissues. The serous coat is provided with a uniform network of capillaries as in the mesentery, and the fatty tissue and glandular elements do not differ in this respect from other similar structures.

The solitary and agminated lymph follicles are provided with elongated capillary meshes, which extend towards the centre of their bodies, and there form loops. The individual follicles are surrounded by a fine network of veinlets (KLEIN[1]).

The most important system, however, is that which is distributed over the villous surface of the small intestine. The researches of HELLER[2] have shown that from the arterioles of the mucosa there arise numerous capillaries. These form networks, with elongated vertically-disposed meshes, around the crypts of LIEBERKÜHN. In the villus, the arteriole passes up towards the apex (in man it ceases near the lower half), where it breaks up into a network of capillaries, which is denser at the summit than at the base of the villus. The capillaries of the villi anastomose

[1] *Atlas of Histology*, London, 1880, p. 221.
[2] *Ber. d. Sächs. Ges.*, 1872.

with those of the rest of the mucosa. The veins commence near the apex of the villus in man and in the rabbit; in the dog, cat, hedgehog, and pig, they take their origin near its base.

THE LYMPHATIC SYSTEM.—The lacteal vessels of the mesentery give off branches, which enter the intestine at its mesenteric border, and pass into its external muscular coat, there to be resolved into a plexus, which pervades its entirety, and which becomes most marked between its two layers. In direct continuity with this system is that of the mucous membrane, which forms a dense plexus throughout the mucosa and submucosa; some of its vessels are perivascular. At the bases of the lymphoid follicles a close plexus which often dilates into sinuses obtains. Many lymphatics also are developed at the attachment of the serous coat with the boundaries of the external muscular zone. In the small intestine each villus possesses a central lymphatic or chyle vessel, or two such vessels may become confluent to terminate blindly within the villus; towards its base the chyle tube becomes narrower and enters the plexus or sinuses between the crypts of LIEBERKÜHN.

THE NERVOUS SYSTEM.—The nerves enter the intestines at their mesenteric borders, and penetrate their external coats to produce a gangliated plexus between the longitudinal and circular muscular layers. This, the *plexus myentericus* of AUERBACH consists of bands of non-medullated fibres, ensheathed in an endothelial membrane derived from the perineurium of the nerve trunks. Every here and there irregularly shaped spaces obtain which contain ganglion cells in chains, rows, or nests; these may be unipolar to multipolar, and only the larger ones are capsulate. The muscular coats are penetrated throughout by a fine plexus of fibrils derived from this large plexus. Other larger bundles of fibrils proceed to the submucosa, where they form a finer plexus—the plexus of MEISSNER, which in its turn gives off still finer branches, to be distributed throughout the mucosa, and reach the epithelial surface. In the large the plexus of AUERBACH is somewhat more highly developed than in the small intestine.

METHODS OF PREPARATION.

The fresh intestines should be washed out with a stream of water, or of normal saline solution, to get rid of the mucus which usually adheres to the epithelial surface; small pieces may then be hardened in chromic acid and spirit fluid, in ordinary rectified spirit, or, best of all, in ammonium bichromate solution.[1] The sections may be stained with logwood, and mounted in Canada balsam or dammar solution.

The blood-vessels may be injected through the aorta, or the superior mesenteric artery, by methods, and with fluids which have already been described.[2]

The lymphatics, especially those of the processus vermiformis, may be injected with a watery solution of Berlin-blue by mean of a hypodermic syringe thrust into the walls of the structure. The hardening of

[1] *Ut supra*, p. 264.
[2] See this journal, pp. 85, 219, etc.

such preparations is best effected in rectified spirit. Sections may be stained with picrocarmine, and mounted in Farrants's solution. An injection of silver nitrate may also be used in the same way; the silver becomes reduced in the cement substance of the cellular elements.

The nervous system requires a special mode of treatment for its effective demonstration. A portion of perfectly fresh intestine should be distended with fresh lemon juice, its cut ends ligatured, and the whole suspended in the same fluid for from five to seven minutes. The lemon juice must now be entirely removed by washing in distilled water, and replaced by a two per cent. gold chloride solution for about half-an-hour. Every trace of the gold must then be removed by rinsing in distilled water, and the tissues placed in a twenty-five per cent. formic acid fluid until the gold has been reduced to a reddish-brown colour. Now, wash the piece of intestine thoroughly in water, and place it in ordinary methylated spirit, or diluted glycerine, to which a few drops of carbolic acid have been added, for a week. At the end of that time, the longitudinal muscular coat with the adherent plexus myentericus of AUERBACH may be readily stripped off with the use of a pair of forceps, and mounted either in Farrants's solution or glycerine, The plexus of MEISSNER may be prepared in a similar way. by teasing the tissues of the submucosa.

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APPENDIX.

SECTION A.

ANIMAL HISTOLOGY.

PAGE 1.—l. 15 from foot of page; for "(*Elasmobranchü*)" read "(*Elasmobranchii*)."
PAGE 3.—l. 2 from foot of page; for "MULLER" read "MÜLLER."
PAGE 5.—l. 23 from top of page; for "HOGAN'S" read "HOGGAN'S."
PAGE 5.—l. 14 from foot of page; for "neuclei" read "nuclei."
PAGE 22.—l. 18 from top of page; for "*vitreous layers* by GLASTAFELN" read "*vitreous layers* (Ger. Glastafeln)."
PAGE 24.—l. 6 from foot of page; for "was" read "saw."
PAGE 70.—l. 22 from top of page; for "wits" read "with."
PAGE 79.—last line; for "racomose" read "racemose."
PAGE 81.—l. 10 from foot of page; for "iver" read "liver."
PAGE 97.—l. 6 from top of page; for "lymphiod" read "lymphoid."
PAGE 111.—l. 17 from foot of page; for "efferent" read "afferent."
PAGE 121.—l. 18 from foot of page; for "admits" read "admit."
PAGE 123.—l. 16 from top of page; for "sulp-indigotate" read "sulph-indigotate." l. 10 from foot of page; for "points" read "point."
PAGE 158.—l. 8 from top of page; for "herinafter" read "hereinafter." l. 19 from foot of page; for "layer low" read "layer of low."
PAGE 160.—l. 8 from top of page; for "them a" read "them in a."
PAGE 220.—l. 17 from top of page; for "182" read "1882."
PAGE 229.—l. 26 from foot of page; for "lymphoid cell" read "lymphoid cells."
PAGE 258.—l. 3 from foot of page; for "*ür*" read "*für*."
PAGE 264.—ll. 9, 10, from top of page; for "lympathic" read "lymphatic."
PAGE 281.—l. 3 from foot of page; for "*Uber*" read "*Ueber*."
PAGE 283.—l. 9 from foot of page; for "mucosa" read "mucosæ." l. 6 from foot of page for "mucosæ" read "mucosa," and for "muscularis mucosa" read "muscularis mucosæ."
PAGE 284.—l. 11 from top of page; for "layer" read "layers;" and for "brancho" read "branches." l. 4 from foot of page; for "*Sangader-system*" read "*Sangadersystem*."
PAGE 288.—ll. 14, 15 from foot of page; for "glanduar" read "glandular."
PAGE 292.—METHODS OF PREPARATION should be placed below l. 6 from foot of page. l. 8 from foot of page; for "plexuf" read "plexus."
PAGE 299.—l. 18 from top of page; for "gland of BRUNNER" read "glands of BRUNNER."
PAGE 300.—l. 9 from top of page; for "*mucosæ*" read "*mucosa*,"

APPENDIX.

SECTION B.

BOTANY AND PETROGRAPHY.

PAGE 9.—l. 6 from top of page; for "A.S." read "A-S," and for "*benk*" read "*beuk.*" l. 7 from top of page; for "*poucha*" read "*puocha,*" and for "*bouche*" read "*buoche.*"

PAGE 10.—l. 25 from foot of page; for "into an equivalent number" read "into a number of equivalent."

PAGE 12.—l. 10 from foot of page; for "*Sapindoceæ*" read "*Sapindaceæ.*"

PAGE 13.—l. 9 from top of page; for "NAGELI" read "NÄGELI."

PAGE 16.—l. 29 from foot of page; for "NAGELI" read "NÄGELI." l. 15 from foot of page; for "*Ban*" read "*Bau.*"

PAGE 17.—ll. 22, 23, 36, from top of page; for "NAGELI" read "NÄGELI." l. 5 from top of page; for "*und Verwandten*" read "*und die verwandten.*"

PAGE 18.—l. 2 from top of page; for "*Surles*" read "*Sur les.*" ll. 21, 22, from top of page; for "NAGELI" read "NÄGELI." l. 18 from foot of page; for "*Suberisee*" read "*Suberised.*" ll. 28-17 from foot of page, should come between ll. 8-6 from foot of page.

PAGE 29.—l. 6 from top of page; for "Κμπειρος" read "Κύπειρος."

PAGE 44.—l. 7 from top of page; for "λίδος," read "λίθος."

PAGE 45.—l. 16 from foot of page; for "LASLAUX" read "LASAULX."

PAGE 46.—ll. 2, 17 from top of page; for "LASLAUX" read "LASAULX." l. 15 from foot; for "chrysolite" read "chrysotile."

PAGE 54.—l. 15 from foot of page; for "GIRKEL" read "ZIRKEL."

PAGE 55.—l. 7 from top of page; for "LASAUBX" read "LASAULX."

PAGE 62.—l. 19 from foot of page; for "FOUQÉ" read "FOUQUÉ."

PAGE 89.—l. 6 from top of page; for "containg" read "containing."

PAGE 104.—l. 2 from foot of page; for "*Thlapsi*" read "*Thlaspi.*"

PAGE 142.—l. 12 from foot of page; for "*Helix hedera*" read "*Hedera helix.*"

PAGE 144 —l. 16 from top of page; for "*Felix fœmina*" read "*Filix fœmina.*"

PAGE 151.—l. 6 from top of page; for "λύκοος," read "λύκος." l. 7 from top of page; for "ποδσς" read "ποδός."

PAGE 156.—l. 10 from foot of page; for "ROPER" read "RÖPER."

PAGE 175.—l. 22 from foot of page; for "proto plasm" read "protoplasm."

PAGE 187.—l. 13 from foot of page; for "*endorcarp*" read "*endocarp.*"

PAGE 188.—l. 18 from foot of page; for "contray" read "contrary."

PAGE 201.—l. 15 from foot of page; for "and others, and are" read "and others, are." l. 12 from foot of page; for "*fructicose*" read "*fruticose.*"

PAGE 213.—l. 17 from foot of page; for "symtheses" read "syntheses."

PAGE 221.—ll. 12, 13 from foot of page; for "linionitic" read "limonitic." On plate, for "Edingburgh" read "Edinburgh."

PAGE 224.—l. 4 from top of page; for "either" read "neither."

PAGE 241.—On Plate; for Fig. II. read Fig. III., and *vice versâ.* l. 2 from foot of page; for "βλαστσς" read "βλαστός."

PAGE 251.—ll. 8, 7 from foot of page; for "Haughtinite" read "Haughtonite."

PAGE 252.—l. 20 from top of page; for "They are not, etc.," read "That they are not, etc." l. 21 from top of page, for "as" read "is."

PAGE 254.—l. 20 from foot of page; for "yenite" read "syenite." l. 5 from foot of page; for "coalescing" read "coalesce."

PAGE 255.—l. 12 from top of page; for "even a mile, etc.," read "even only a mile, etc." l. 12 from foot of page; for "throw" read "thins."

PAGE 256.—l. 14 from top of page; for "which" read "while."

PAGE 260.—l. 7 from top of page; for "SACH'S" read "SACHS."

PAGE 275.—l. 10 from foot of page; for "distinguishd" read "distinguished."

PAGE 277.—l. 21 from top of page; for "pottasium" read "potassium."

PAGE 279.—l. 6, 7, from top of page; for "*compestre*" read "*campestre.*"

PAGE 286.—l. 20 from foot of page; for "envelop" read "envelops."

PAGE 315.—l. 5 from top of page; for "ROWLEY" read "ROWNEY."

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STUDIES IN

MICROSCOPICAL SCIENCE,

EDITED BY

ARTHUR C. COLE, F.R.M.S.

VOL. II.

WITH THIRTY-SIX LITHOGRAPHED PLATES.

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PREFACE.

The first volume of the "STUDIES IN MICROSCOPICAL SCIENCE" consisted of a series of Essays which, though each was complete in itself, had little connection with each other. In the present volume an attempt has been made, in the Sections devoted, respectively, to Animal and Botanical Histology, to work out a special subject in so far as the series of twelve short essays in each section admitted of such treatment. My best thanks are due to Mr. W. FEARNLEY, who contributed the Section in Animal Histology; to Mr. DAVID HOUSTON, F.L.S., F.R.M.S., Lecturer on Botany and Biology at the Birkbeck Institution, who undertook the Botanical Section. Both these gentlemen kindly contributed to the "POPULAR STUDIES," in which Section also I was greatly assisted by Mr. FREDERICK GREENING, Lecturer on Animal Morphology and Histology at the Birkbeck Institution. Mr. Fearnley rendered most valuable assistance in respect of the "METHODS OF MICROSCOPICAL RESEARCH;" whilst the very elaborate and beautiful drawings from the preparations were contributed by Mr. EDWARD T. DRAPER, to whom I offer my warmest acknowledgments. The preparations were made by my son, Mr. MARTIN J. COLE (Instructor in Practical Microscopy at the Birkbeck Institution), and myself. I desire to express my grateful sense of the very kind and appreciative notices and reviews accorded to the "STUDIES" by the Editors of the "JOURNAL OF THE ROYAL MICROSCOPICAL SOCIETY," 'SCIENCE GOSSIP," "ILLUSTRATED SCIENCE MONTHLY," "THE MICROSCOPICAL NEWS," and numerous other Journals in this country and America.

ARTHUR C. COLE.

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APPENDIX.

SECTION I.

ANIMAL HISTOLOGY.

PAGE 9.—l. 5 from foot; for "cartilage is tissue" read "cartilage is a tissue."

PAGE 11.—l. 2 from foot; for "the white corpuscles is not," &c., read "the white corpuscle is not," &c.

PAGE 25.—l. 11 from foot; for "their areolar character of is shown" read "their areolar character is shown."

PAGE 29.—l. 14 from top; for "the proportion of carbon and hydrogen" read "the proportions of carbon and hydrogen."

PAGE 44.—l. 13 from foot; for "solution of aniline blue black make as follows" read "made as follows."

PAGE 45.—l. 15 from top; for "cemetrical" read "symmetrical."

PAGE 48.—l. 2 from foot; for "and as it has been the means" read "and it has been the means."

STUDIES IN MICROSCOPICAL SCIENCE.

SECTION I.—ANIMAL HISTOLOGY.

CHAPTER I.

THE MORPHOLOGY OF THE CELL.

Although the term *histology*[1] literally signifies, a discourse about tissues in general, its meaning in natural science is now limited to a consideration of only the minute details of structure. Histology then, is pre-eminently a microscopical science; and animal histology is concerned exclusively in the investigation of animal tissues.

As in physical science the chemist builds up his system of philosophy out of atoms endowed with energy, so the histologist commences with his elements,—cells imbued with life. A distinction must be drawn between anatomical and physiological histology; the former deals with the shapes of cells and their relation to each other, the latter treats of their functional activity or life. It is only with anatomical histology that we are at present concerned, and our first inquiry must be confined to the ultimate element from which all tissues arise or are built up, and which has been termed the *morphological unit* or *cell*.

THE CELL THEORY.—Since the discovery of the cellular nature of animal tissues by SCHWANN[2], in 1835, there has been much diversity of opinion as to the true nature of the morphological unit. Some have asserted that it consists of a minute mass of indifferentiated protoplasm; that is to say, protoplasm in its most elementary condition, without any sign of structure,—not even a separation into an outer dense and an inner soft layer; others have taken up this primordial particle and have held it to be the ultimate condition from whence every morphological unit derives its existence, and, when it is in this primitive state, have considered that it deserved some special name, wherewith to distinguish it from all other things, and the *cytode*[3], as it was called, ranked as a sort of histological Adam.

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[1]Gr. ἱστος, web, tissue; and λόγος, discourse. Also written *Histiology*, from Gr. ἱστίον, tissue.

[2]*Mikroskopische Untersuchungen*, Sydenham Society's translation, London, 1847, p. 165.

[3]From the Greek for cell, κύτος; the term *cell* is derived from the Latin *cella*, akin to *celare*, to hide, conceal, hence a small closed cavity or hollow place.

But this varying nomenclature came to be only confusing, and the name *cell* once more regained its ascendancy. But it was found that as the history of the lower forms of animal life were studied and revealed, that they were nothing more nor less than single cells, it was still an open question what the cell essentially consists of. Hypotheses of their precipitation, and subsequent modification were not wanting to account for their existence. Most observers, however, agreed that the outer part, which is usually firmer in texture, was not essential, but only the result of development, and the cell-wall ceased to trouble naturalists. But, within the cell, there often exists a denser portion, usually of spherical form, and this *nucleus*, and its contained *nucleolus*, were long looked upon by some observers as the necessary origins of the cell; their conclusions being based upon the fact, that when nucleated cells multiply they generally do so by a division through the nucleus, and greater weight was attached to this, inasmuch as in all previously observed cases of sexual generation those of the nucleus heralded all subsequent changes. Moreover, amongst the unicellular animals, known as *Infusoria*, so active do the nucleus and nucleolus become, that a specialisation of function, the function of reproduction by sexual generation, was assigned to them. The importance of the nucleus to the cell falls to the ground, however, when we come to consider that there is a legion of forms which do entirely without a nucleus throughout the whole of their lives, and that, indeed, this distinction of nucleated and non-nucleated cells has been taken advantage of in a natural classification of these lowly organisms, which thus admit of a division into *Monera*[1] and *Endoplastica*.[2] Superadded to this there is the incontestible fact that nucleated cells, even amongst the highest order of animated beings, often subdivide in their development, independently of their nuclei.

From what has been stated, it will be clear that all attempts at a nomenclature which seeks to designate any single definite thing as a cell, must of necessity be futile, for the morphological unit varies, not only in its nature from the very commencement, but in the course of its individual development. Thus, the simple mass of undifferentiated protoplasm known as *Protamœba*, originates as *Protamœba*, and often remains a fixed type; but it may change, it may develop a nucleus and contractile vesicle, and become an *Amœba*. *Amœba* itself may reproduce young *Amœbæ*, which do not differ in any way from the parent organism, and which grow thereafter, but in size only. Other cases commence as *Amœbæ*, but subsequently develop into more complex forms, *e.g.*, *Hydra*.

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[1]Gr. μονός, single, an order of *Protozoa*, embracing those forms whose bodies consist of simple undifferentiated protoplasm.

[2]Gr. ἔνδον, within; πλαστός, formed; nucleated *Protozoa*.

Each cell of the adult *Hydra* assumes a columnar, or rather a cuboid shape, is nucleated, and possesses an outer membranous envelope, sometimes only recognisable as a denser hyaline portion.

Amongst the higher animals, most of the tissues of the body, save those of certain glandular organs, are composed of aggregates of nucleated cells with well-defined cell-walls. In the course of growth, some of these cells are cast off from the economy, as mere cell-walls, their contents have vanished, and they are no longer of any use to the body; they exercise a protective function to the cells beneath them for a time, and are thereafter discarded; familiar examples of such cells may be seen all over the general surface of the body; they may be readily obtained from the region of the scalp in man, whence their detached elements are known as "scurf," in the external ear, near the roots of the nails, and the transitional or red portion of the lips they are most noticeably abundant, and can easily be procured for examination; in certain local and temporary irritations, such as chaps and blisters they are sometimes too evidently manifest, and in chronically diseased conditions, as in psoriasis and scurvy, they are painfully present.

But there are other cells in the body which also ultimately lose their nuclei and cell-contents, but, in so doing, accumulate an amount of matter, in their cell-walls, upon the passive mechanical properties of which their physiological functions depend. The enamel fibres of the teeth, in all the higher animals, afford excellent illustrations here, for they consist entirely of thickened calcified cell walls of peculiar elongated shapes, apposed to one another.

In the mucous membranes, all the superficial cells of their secreting surfaces are of columnar or sub-columnar shapes, and possess nuclei, but every here and there, one of the cells assumes a globular shape, its upper rim bursts, and its contents are partially discharged; by some observers these goblet-cells are looked upon as unicellular glands, with a mucin secreting function, by others they are regarded as the degraded equivalents of the dead scales of the skin noted above, and make room, in this manner, for the younger cells, which are destined to take their places.

Yet a little more deeply seated, within the true glands of the body, the cells are devoid of any distinct envelope, but are possessed of well-developed protoplasmic bodies of a firm consistency, and are nucleated.

Other tissues of the highly organised animal body present cells which are nucleated and possess both protoplasm and cell-walls, yet they lie imbedded in a substance which it is difficult to account for, and which would defy the labours of the histologist, unless he studied the growth of the tissues in question. For instance, the whole group of the connective tissues present this phenomenon—that their cell-walls are being constantly produced from the protoplasm within, which divides, and gives

rise to new cells, which, in their turn, form new cell-walls, until a certain stage is arrived at, when further development ceases. Concurrently with these changes of growth, the outer moieties of the cell-walls become fused together to produce a more or less homogeneous intercellular substance, known as the matrix in hyaline cartilage, whilst the cells themselves retain their individuality intact, that is, they are possessed of protoplasm, nucleus, and cell-wall; the change goes a little further, and the homogeneous-looking matrix becomes fibrillated, in which case the varieties of tissue, known as white fibro and yellow fibro cartilage result, the difference being manifested in a preponderance of the gelatigenous element in the former, and of the elastic element in the latter instance. In every case, however, the cartilage cells remain of an ovoid form; where they subsequently throw out processes, and where the matrix becomes highly calcified and the original cell-wall, too, takes up lime salts, the branches, anastomose, and, finally, the protoplasmic cell processes are withdrawn, the structure known as bone is the result.

To diverge in yet another direction, the cells may throw out filaments which anastomose, and form a reticulated structure; at the same time, they produce a jelly-like material in the interspaces of the reticulum, that is known as mucous tissue, and is the transitory form of embryonal tissue; it obtains permanently in the vitreous humour of the eye. The fœtal mucous tissue develops still further with the growth of the animal, and the mucous intercellular matrix becomes fibrillated; when the gelatigenous element is in excess it is called white fibrous tissue; when the fibres are chiefly composed of the elastic element it is said to be yellow fibrous tissue. Some of the cells of the connective tissue withdraw their filamentous processes or may never develop them; in this condition they possess the power of locomotion, and are termed wandering cells; others remain fixed and immovable, clasping the fibres which they combined to produce, whilst a third set remain fixed, but slowly change their form.

There is yet another interesting type of tissue called retiform or adenoid tissue, which is composed of a dense reticulum organically derived from the coalescence of branched cells. The network thus produced may give rise to cells of other shapes by a process analogous to gemmation, and superadded to all this the interspaces of the reticulum may be filled with corpuscles derived from quite another source, viz., the lymph. Adenoid tissue is characteristic of the spleen and lymph glands in general.

Muscular and nervous tissue again, form a departure from the normal type of the cell in very marked ways. Whilst their cell walls and nuclei remain but slightly altered except in form, their protoplasmic contents undergo profound changes, resulting in the case of striated muscle in a peculiar banded structure, the true nature of which is still involved in considerable obscurity, owing to the complicated questions which have arisen from imperfect illumination and the use of the high powers of the microscope which are required for its elucidation.

Yet all these diverse forms of elements have been called *cells;* from the independent little *Protamœba*, with its apparently structureless jelly-

like body, through the passive calcified cell-wall of the enamel fibres of the teeth, to the complicated cells of striated muscular fibre. No rational attempt to classify them was made until recently, when RUTHERFORD[1] did so in a clear exposition to his students in the University of Edinburgh. The following is a slight modification of his generalisation :—

A cell may be any one of the three following things :—

1. A protoplast, with or without a periplast.
2. An endoplastic or nucleated protoplast, with or without a periplast.
3. A periplast from which both protoplast and endoplast have vanished.

From what has already been stated, it will be gathered that the term cell may be employed to denote a vast variety of forms. It may be pointed out here, however, that even the nomenclature of RUTHERFORD is to a certain extent ambiguous and in more ways than one. For instance, amongst the lowest forms of life there are structures of the simplest description which in certain stages would be classed under the first category, *i.e.*, as simple non-nucleated protoplasts ; but when their life-history is worked out, they can no longer be looked upon as single morphological units, for they are shown to be composed of a number of cells which have coalesced to form a *plasmodium* in which no trace of former aggregation can be detected. The plasmodium of HAECKEL'S *Protomyxa* is of this nature, and amongst certain plants *(Myxomycetes)* the formation of plasmodia is the rule, not the exception. Then again,in speaking of the cells of ordinary connective tissue, only the corpuscular elements are taken into account, although in strict conformity with the definitions given, the fibres of the matrix ought also to be included. So also, in describing the cells of hyaline cartilage, the matrix which they produce should be considered. It would be well if the term *corpuscle* could be retained for such structures as are only the partial derivatives of single cells or morphological units, and the term *cell* confined to the total product of each unity ; in that case the word *blood-corpuscle* would have to be abandoned for *blood-cell.*

The three parts which enter into the structure of a typical cell, are (1) protoplasm, (2) cell-wall, (3) nucleus. The protoplasm is the chief amongst these, inasmuch as without it the cell could not exist ; every cell at some stage or another of its life possessed protoplasm as an integral part, and every living and growing cell possesses protoplasm. The cell-wall may or may not exist, and is, therefore, only of secondary importance, although it may finally come to be the most essential portion of the cell, as in the enamel fibres of the teeth, and in the red blood-cells of the *mammalia.* Unlike the protoplasm, the cell-wall, although endowed with life, is incapable of multiplication ; it cannot of itself, give rise to new cells, whereas the protoplasm can become the seat of cell multiplication. The true nature and functions of the nucleus, with or without its contained vesicle and nucleolus, is not yet understood. Its prevalent division, previous to the division of the protoplasm in cell multiplication, long caused it to be invested with undue importance. The ten-

1 *A Text Book of Physiology,* Edinburgh, 1880, pp. 27, 29, 30.

dency now is to regard it as merely a denser portion of the protoplasm, and to doubt its importance as a peculiar structure; until its functions are definitely ascertained, however, it would be presumptuous to attach either an undue value to, or to underrate it. In the young condition of cells which possess nuclei, the latter are of spherical form, and more or less central in position. As the age of the cell advances, the nucleus shows a tendency to assume a parietal position, and to become oval, or even quite flattened. It always exhibits a greater affinity for such re-agents as aniline dyes and carmine than the surrounding protoplasm, and is not so rapidly acted upon by acids and alkalies. On chemical analysis, in certain cells, at all events, *e.g.*, pus, it yields a special albuminoid substance, *nuclein*, which is absent from ordinary protoplasm. The researches of KLEIN, FLEMMING, and others have shown that it possesses a minutely reticular structure, which they term *intranuclear*, in contradistinction to the *intracellular* reticulum, which they have detected in the general protoplasm of the cell. Within the nucleus, one, two, or more nucleoli, may sometimes be observed. These are usually of denser formation than the nucleus itself; their function has hitherto been merely a matter of guess work, and, on account of extreme minuteness, their chemical constitution has not been discovered. Sometimes the nucleus contains a space or vesicle, which is revealed by the double contour of that body under a high power of the microscope.

The reader can readily verify what has been said regarding KLEIN'S demonstrations of an *intranuclear* and an *intracellular* reticulum. Many old horse-ponds contain the common newt or eft, which is easily caught in a small net. Take two newts, confine one in a small quantity of water for a few days (usually about four), and the whole epidermis will be shed as a fine film, giving a complete cast of the entire animal. Place a snip of this in absolute alcohol for twenty-four hours; also, another snip in a saturated aqueous solution of picric acid for the same length of time. A small piece of the former may be stained in logwood solution, and mounted in Farrants' medium, whilst another small piece, hardened in the picric acid—after being washed free from the acid—may be stained in picro-carmine for an hour or more, and also mounted in Farrants' medium. As the film is extremely thin, care must be taken to press the cover-glass down upon the slide, or a flat field will not be obtained. Either preparation will prove a permanent slide, and beautifully demonstrate the intracellular network of fibrils. Cells sometimes have a *granular* appearance, due to the ends of these fibrils being in focus. The other newt must be killed, its mesentery carefully removed, and placed in a five per cent. aqueous solution of chromate of ammonium for twenty-four hours. At the expiration of this time, wash it free of the solution, then snip off a piece, and stain it for several hours in picro-carmine and mount it in Farrants' medium. This also must be well flattened upon the slide in order to obtain a flat field. It exhibits the *intranuclear* fibrillation in the cell of the numerous, half-isolated (in some cases wholly isolated) non-striated muscle fibres. The *protoplasm* of cells has so strong an affinity for the ordinary staining fluids that its bare existence can be easily and con-

stantly detected by the observer when examining parts of plants and animals. It is watery to some extent, but will not mix with water in the living cell. Real granules are frequently imbedded in parts of the hyaline substance of the protoplasm; globules of watery fluid also are sometimes to be observed. The chemistry of protoplasm has not yet been decided, but it is, at least, similar to albumen and usually neutral in re-action, or weakly alkaline. The great elasticity of protoplasm is seen in the cells lining the bladder, the arteries, the air vesicles of the lungs and the pleura. The most interesting feature to the observer, and the most important property of protoplasm, is its curious powers of movement. These are truly wonderful, and are easily observed, but as the movements are slow and uncertain, the observer must exercise patience, and devote, at least, an hour to their study, during which his observation must be continuous. He will also gain a better idea of the attitudes assumed by the protoplasm by sketching, at stated intervals, the form of the cell he is watching, and then comparing the sketches. The best specimens for this purpose are the *Amœbæ*, minute organisms to be found in stagnant water, in mud, or in damp earth. These have the appearance of a particle of jelly. The most readily obtainable masses of living protoplasm, however, if the observer does not object to the prick of a fine needle, are the white corpuscles of the blood. A handkerchief is wrapped tightly round the finger, which is then pricked, and a minute drop of blood placed on a clean slide. The slide is laid on a warm stage—a piece of copper plate, pierced with a hole, will answer the purpose, provided it be long enough to extend beyond the stage, so that a spirit lamp may be used to warm it. The heat must be carefully regulated, because if too great warmth be applied, the movements will cease. Some observers place solid pieces of Cacao-butter on the slide, as beacons for this purpose. Should the white blood-corpuscle be under observation the changes of form will be found to be very similar to those of the amœba, but slightly less active. The first thing to strike the observer is the formation of a *pseudopodium*, which appears as an elevation on some part of the cell, this increases in size, and currents carrying granules flow into it. Sometimes an incoming and an outgoing stream of granules may be seen in one and the same protrusion. It is by means of this throwing out of pseudopodia that the cell is enabled to move from place to place. The process is extruded, the rest of the body follows, and in this manner progression is achieved. *The ingestion of foreign particles* is also a phenomenon easily seen in the protoplasm of amœbæ or the white blood corpuscles. The blood of the newt, by preference, is taken, on account of the larger size and number of the white corpuscles. Take fine granules of carmine, vermillion, indigo, or of aniline blue, which has been precipitated by alcohol from an aqueous solution. These may be mixed with water, or with white of egg, 1 part, and salt solution ($\frac{3}{4}$ %) 2 parts, and strained through muslin. The blood is placed on a slide, and a ring of oil run around the cover to prevent evaporation, and the slide placed upon a warm stage—less warm in case of newt's blood being used. Cohnheim proved the practical importance of feeding the white blood-corpuscles with these pigments, by injecting, for several days in succession, 2 or 3 cubic centimetres of water, containing fine

particles of aniline blue, into a subcutaneous lymph-sac of the frog. The lymph-corpuscles enveloped the blue granules, and entered the circulation. After some days he induced inflammation of the cornea, and found among the pus-cells at the seat of irritation some containing the blue granules, thus proving that they had *emigrated* from the blood-vessels into the corneal tissue. This experiment establishes the assertion that the protoplasm of cells is capable of movement from part to part, and is also capable of enclosing particles with which it comes into contact. The particle will be first observed to adhere to the surface of the protoplasm; then processes from the protoplasm are thrown out around it and by them withdrawn into the interior, where it may remain some time, being carried hither and thither by any currents that may happen to be flowing in any part of the interior, and, of course, carried bodily with the protoplasm wherever that may wander. After a while it may be expelled. Variations of temperature influence the movements of this protoplasm; thus, in warm blooded animals, any cooling of the protoplasm below 10° Cent. causes cessation of movement, which, however, is resumed on restoring the warmth; the activity being heigthened up to, and a little beyond, the temperature of the body from which the protoplasm has been drawn, to cease, however, if the abnormal temperature be long continued. *Oxygen*, also, is requisite to keep protoplasm in its active state, though it can go on for a short time without a fresh supply. *Water* appears to act as a stimulant, or rather, perhaps, as an irritant: if absorbed to a slight extent, the protoplasmic movement is accelerated: beyond this, it is destroyed. *Alkalies*, also, when very dilute, act like water upon it, to some extent, but not so acids. The vapours of chloroform and ether rather arrest the movement without destroying its capability, which may be seen to reappear soon after the vapours are withdrawn. Should the student wish to apply these vapours or gases, he can easily do so by placing a drop of the substance on a slide, with a glass cell around it, and then viewing the protoplasm as it adheres to the cover glass, its under surface, of course, being placed over the glass cell.

The preparations of *Globegerina ooze* and of *Polycystina*, have been selected as showing the elaboration of *calcareous* and *siliceous* tests, respectively, by unicellular organisms; as exhibiting the animal cell in its most complex form; and as typical examples of the Foraminiferous and Radiolarian groups. The calcareous shells of *Globegerina bulloides* consist of nearly spherical chambers, progressively increasing in size, and opening into a vestibule common to all. In the living state, floating Globegerinae are met with in the surface waters of the Ocean, and were caught in "tow-nets" by the scientists of the "Challenger" expedition. The shells, during life, will be found to be furnished with numerous delicate calcareous spines, which extend themselves radially from the angles at which the ridges meet to a length of four or five times the diameter of the test. At the bases of these spines the sarcodic substance exudes through the pores of the shell, forming a flocculent fringe around it, which extends itself on each of the spines, creeping up one side to its extremity, and passing down the other with a peculiar flowing movement. The whole of this sarcodic extension is retracted, if a drop of an irritant fluid be added to the water containing the organisms.

Sir Wyville Thomson maintained that these organisms only live at, or near, the surface, and that, when they die, they lose their spines and sink, thus occasioning a continual rain, so to speak, of Globegerinæ to the ocean floor; whilst Dr. Carpenter asserts that they have been found living at the bottom, having passed part of their lives in the upper waters and sunk when the thickening of their shells rendered them too heavy to float; whilst many types pass their whole lives at great depths. The Foraminifera may be caught, and their habits studied, by carefully examining sea weeds, zoöphytes, etc., to which they adhere. The *pseudopodia* of Polycystina radiate in all directions from the deeper portion of the extra capsular sarcode, and in some species are branchiate and anastomose, whilst in others they are enclosed in hollow rods, which form part of the siliceous skeleton, and issue from the extremities of these. A flow of granules takes place amongst them, and they feed on diatoms and other minute algæ, marine infusoria, etc., in the manner already described.

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THE BLOOD.

BLOOD OF FROG, DOUBLE STAINED.

× 400

Etymology.—Blood *n.* [Anglo-Saxon *blôd*, Gothic *blôth*, Icelandic *blôdh*, German *blut.*] The fluid which circulates through the arteries and veins of men and animals. This is a rough definition. It is more correct to say, that it is the great carrying agent of the body which supplies itself and the remaining parts of the body with air and pabulum, and bears away the used and noxious parts of the various tissues to their respective outlets.

DESCRIPTION.

Blood may be roughly regarded as consisting of a *fluid* (plasma) in which are suspended a number of more *solid* bodies (the red and white corpuscles). If we take hyaline cartilage and blood and compare them we have cartilage corpuscles fixed in a firm "setting." The matrix on the one hand, and blood corpuscles floating in a liquid setting the plasma on the other. Blood is thus seen to be a tissue as cartilage is a tissue. It is the great medium of exchange between all parts of the body. Its universal distribution in the body has led Bernard to remark that it is *an internal medium* bearing the same relations to the constituent tissues that the external medium,

the world, does to the whole individual. Just as the whole animal organism lives on the things around it, its air and food, so the several tissues live on the complex fluid by which they are all bathed, and which is to them their immediate food and air. From this it follows that the composition and characters of the blood must be for ever varying in different parts of the body, and at different times.

It is, therefore, with the above understanding that we now proceed to give a physical analysis.

The blood within the arteries is scarlet: within the veins dark purple. It is slightly heavier than water, its sp. gr. being 1·055. It is saltish to the taste, with a slight alkaline reaction, and an odour in all cases peculiar, but in some cases so peculiar that one can at once tell the source from which it comes. The naked eye appearance of homogenity is deceptive, as plainly shown with the microscope whilst in the animal body, by taking a transparent living tissue, such as the web of a frog's foot, frog's mesentery, bat's wing, fish's tail, etc. A drop of blood on a slide, also reveals its complex character, when viewed through the microscope, with even a low power.

The liquor sanguinis or plasma, when the blood is drawn from the body, separates into two parts, a solid and a liquid. The solid gradually becomes solid, and in doing so contracts and squeezes out the liquid. This solid is called *fibrin*, and the liquid it expresses *serum*. In becoming solid the fibrin encloses the corpuscles, and then we have a *clot* with liquid serum on its surface. In other words; if we catch blood in a vessel, such as a basin, as it flows from the body, then let it stand, we find it form two substances, a liquid, the colour of straw; and a solid, almost scarlet. The coloured clot is, as we have said, fibrin, that has entangled red corpuscles and has shrunk. In clotting, the fibrin contracts in all directions, therefore we find its surface saucer-shaped: its sides have shrunk away from the sides of the basin, and the serum it has squeezed out floats both on it and around it, and slightly beneath it. Quain (vol. ii. 9th Ed.) gives a diagram of the above; thus:—

Liquid blood { Corpuscles... ... ... } Clot
Liquid blood { Liquor Sanguinis { Fibrin } Clot } Coagulated blood.
Liquid blood { Liquor Sanguinis { Serum . . } } Coagulated blood.

If we tie a handkerchief tightly round our finger, then prick the end of the finger with a small sharp needle, then place the minute drop of blood which oozes forth on a perfectly clean slide, and cover it, using very gentle pressure to flatten it well out, we find abundant pale-straw coloured corpuscles (the red corpuscles), and here and there a colourless globular body (the white corpuscle). After a while the red corpuscles collect into rolls like a pile of pennies. These red corpuscles are, in man, biscuit shaped: that is, they are round and thicker at the edge than in the centre. Technically speaking, they are biconcave discs. Their average diameter, they vary slightly, is about $\frac{1}{3100}$th of an inch. Should the light pass through several of these, then we see that they are red. These red corpuscles are elastic and very compressible, as may be seen during their circulation. Vierordt calculates that there are 5,000,000 red corpuscles, and 10,000

white corpuscles in a cubic millimeter of healthy human blood. The number of these corpuscles relatively varies much. In fine, healthy, human blood there will be 1 white corpuscle to about 500 red ones. Then, again, those living in towns do well if they can keep the ratio at 1 in 300. Further, in the anæmic the proportion is still lower.

In structure, the red corpuscles are formed of a colour giving crystallizable substance called *hæmoglobin*, and a colourless part called the *stroma*. Water readily dissolves hæmoglobin, so that if a drop of water be added to the drop of blood, the red corpuscles discharge their hæmoglobin and remain spherical colourless bodies. Many other agents also dissolve out the hæmoglobin, dilute acids among these. If a weak solution of tannic acid be used the hæmoglobin is discharged, but being insoluble in the tannic acid it adheres to the surface of the colourless stroma like a dark coloured globule. After its escape from the red corpuscles the hæmoglobin crystallizes into elongated prisms. Rutherford gives the following method for obtaining a permanent preparation of hæmoglobin for the microscope :—"Kill a rat or mouse by the inhalation of ether. Place a drop of its blood upon a slide, and add twice its volume of water. Mix the two with the point of a needle, and allow slight evaporation. Prismatic crystals, either isolated or in rosettes, will be found. These may be preserved by allowing the blood completely to dry before the application of the cover-glass, and then applying a drop of dammar or balsam solution and covering."

The stroma of the red corpuscle, after the hæmoglobin has been washed out, is found to be composed of paraglobulin, cholesterin, and protagon. (Quain).

The blood of the frog which accompanies the present number is seen to differ from the above description mainly in the red corpuscles being nucleated, and the corpuscle being oval, not round. Water causes both nucleus and stroma to swell up, and the coloured part to withdraw. Both coloured matter and nucleus can be expelled from the red corpuscle of the newt or frog by a 2 per cent. solution of boracic acid. One or two nucleoli within the nucleus of the amphibian red corpuscle can be brought into view by dilute alcohol. The nucleus contains a close network giving to it a granular appearance. The nucleus is of the same shape (oval) as the corpuscle itself, and is about one-third the length of the latter. Very likely the term nucleus, and our regarding the nucleus as a separate entity is misleading; because it is not visible in the red corpuscle of the amphibian *within* the body, and in its normal surroundings.

With regard to the existence of an enveloping membrane there are two schools: one which says there is, and adduces as proof, that the action of certain fluids upon the red corpuscle is osmotic, and causes the corpuscle to swell out from the discoid shape to the globular, or to shrink and become crenated, according to the reagent used. The other school refuses to accept this as evidence, and asserts that if the interior of the corpuscle be more fluid than the exterior, the osmotic action would still be present. The latter also point to the fact that no one has ever seen a separate cell wall.

The white blood-corpuscles is not quite so familiar an object, as it requires looking for in examining human blood. Only students see it, on

account of its scarcity, one white corpuscle in hundreds of red corpuscles. In our article on the cell, the properties of these remarkable bodies are dwelt upon at length, the most remarkable among which is the change of form. Ordinarily, however, we may safely regard them as spherical, and any form they assume that is not spherical records a degree of movement, the power being inherent in the corpuscle, and capable of being aroused, as has been already stated, by warmth and other stimuli. They are somewhat larger than the red corpuscle, being about the $\frac{1}{3500}$th part of an inch in diameter. As has been described, it is a minute protoplasmic structure, enclosing one or more nuclei.

Besides red and white corpuscles, there are other bodies discernible, the chief among which are minute round colourless particles, *elementary particles* of Zimmermann or *hæmatoblasts* of Hayem.

Double Staining of Amphibian Blood.

The preparation which accompanies this number has been stained according to the method, slightly modified, of Dr. Allen Y. Moore as described in "The Microscope and its Relations to Medicine and Pharmacy," vol. ii., No. 3, Aug. 1882. Two solutions are used, named respectively A and B.

Solution A.

Eosin	...	...	5 grains
Distilled water	...	...	4 drams.
Alcohol	...	...	4 drams.

Dissolve the eosin in the water, then add the alcohol.

Solution B.

Methyl aniline green	...		2 grains.
Distilled water	...	...	1 ounce.

Having chloroformed a frog its head is cut off and the blood taken from the parts, or the frog is pithed and blood taken from the heart. Dr. Moore directs the drop of blood to be placed on one slide and the edge of another slide to be drawn over this to spread it out. After spreading it is allowed to dry, then it is flooded with solution A for a few minutes: then the slide is dipped and agitated in clean cold water a few seconds; then it is flooded with solution B a few minutes, and again agitated in water to wash off the surplus stain. It must now be set aside out of the way of dust till quite dry, then balsam or dammar added, and the cover put on.

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EPITHELIAL TISSUE.

× 400 diameters.

Etymology.—From the Greek ἐρι, *upon*, and θελε, *a nipple.*

Most of the free surfaces and membranes of the body are lined by epithelium. It is found on the surface of the skin, also on the inverted skin (mucous membrane) which lines the alimentary canal, lachrymal, nasal, tympanic, respiratory, urinary, and genital passages, and the various glandular recesses and ducts which *open into* these various passages. Then again, under the name of endothelium (from endo, within,) it covers the free surfaces of the serous membranes, which line the *closed* cavities (chest, abdomen, etc.) Lastly, it covers the inner surfaces of the heart, blood, and lymph vessels.

The classification of the various epithelia may either be according to function, or according to shape and arrangement. It will suit the purpose of our present study to use both classifications, taking the latter first.

There are three forms, the first of the three having four varieties. We may tabulate them thus :—

1.—Simple :—
- *a.* Pavement.
- *b.* Columnar.
- *c.* Spheroidal, or Glandular.
- *d.* Ciliated.

2.—Stratified.

3.—Transitional.

The simple is so called because it is made up of a single layer.

a. Pavement Epithelium.—This is the most extensive variety of the simple. It is composed of flattened cells joined at their edges, or, rather, lying edge to edge like the flags of a causeway. Between each cell is a so-called cement substance, invisible, but which can be stained black with weak solutions of silver nitrate, and thus brought into view. Each cell contains a nucleus, and this, again, contains nucleoli. In order to demonstrate this, scrape the inside of the mouth with the nail or a blunt knife: place the scrapings on a slip, with a covering glass; then irrigate with a weak solution of magenta. To demonstrate the cement sub-

stance open the abdomen of a fresh-killed frog, or toad, turn aside the bowels and stomach, then pour upon the loins—roughly speaking—a half per cent. solution of silver nitrate in distilled water. This floats up the *septum cystern lymphatica magna* as a film or delicate membrane. After a few minutes it turns milky or greyish; then shower upon it a quantity of common water: snip a bit away: float it from water on to a slip: apply a drop of glycerine, then a cover, and expose, to diffuse daylight, till it becomes slightly brown. We now have a choice specimen of pavement epithelium, the silver lines disclosing jagged edges of cells and some straight edges, the cells being polygonal. This variety lines the serous membranes, vessels (blood and lymph); also the alveoli of the lungs, &c.

b. COLUMNAR EPITHELIUM.—This variety of the simple is also called cylindrical, because it is irregularly cylindrical in shape. A view of the surface is not unlike the pavement variety, because the columns are so closely packed together that their sides are pressed into the polygonal shape. When a side view is taken the columns are seen pressed together, their attached ends resting upon a membrane called basement membrane. The specimen sent with this number, and the plate, shew them perfectly. The attached end tapers to a point, whilst the free end is broad. Each contains an oval nucleus, and this has an intranuclear network. The vacuoles in the protoplasm of the cell give it a granular appearance. The free or broad end has a striated appearance, and these striae rest on a light-refracting well-defined thin disk. The striae have the appearance of cilia. Columnar epithelium is found lining the intestines, &c.

c. SPHEROIDAL (GLANDULAR) EPITHELIUM.—This variety of the simple is made up of globular cells, which by mutual pressure are often polyhedral. It is found in the terminal portions of tubular glands, and is therefore called glandular. A good specimen may be obtained by putting pieces of a fresh liver of the newt into a five per cent. solution of chromate of ammonium for forty-eight hours, and, after washing away the solution, teasing in glycerine. If stained in picro-carmine for a few hours before teasing, the nucleus and its intranuclear network are brought out.

d. CILIATED EPITHELIUM.—This is perhaps the most interesting of the epithelia, and is well shewn in the accompanying preparation. It lines the air passages: the mucous membranes and glands of the uterus, also the Fallopian tubes: the central canal of the spinal cord, and parts of the ventricles of the brain, &c. The cilia are placed on a disk like the striae mentioned above, and have a lashing movement similar to that of a field of corn with the wind passing over it. The cilia have carrying properties which we can demonstrate thus:—Kill a frog and decapitate it, remove the lower jaw, and place the head with the roof of the mouth upwards on a table. Now place a minute crumb or other substance upon the anterior part when it will be seen to travel slowly towards the gullet. The cilia, according to Klein, are in continuity with the intracellular network.

The nucleus is very large, and contains a very distinct nucleolus which refracts the light more strongly. Cilia in motion may be studied by placing a piece of the gills of a mussel on a slip and adding a drop of the water, collected in a watch glass, which escapes on opening the shell. Mr. Lister was the first to show that the vapour of chloroform slowed the movement and enabled us to see the anatomy, so to speak, of the ciliary movement. A glass cell is placed on the slip, a bit of the mussel's gill is placed upon a cover glass, in sea water, collected as before stated, and the cover inverted over the cell in which a very minute drop of chloroform has been placed. The movement gradually becomes slower and finally stops; when moving very slowly we see its action perfectly.

2. Stratified Epithelium.—This is the second form, and is so called because it lies in layers one above another, each layer becoming flatter as the free surface is approached. The layers assume the following shapes:—The deepest are irregularly columnar: then these are superimposed by cells irregularly polyhedral; these, again, are succeeded by cells a little flatter, and these, again, by cells almost absolutely flat. In other words, the cells, from being protoplasmic, soft, and "fleshy," become gradually flat, dry, and "horny." The nucleus with its intranuclear network is well seen in the lowest cells: it is oval, with its long axis at right angles to the surface on which the cell rests. Then the nucleus becomes spherical, and afterwards again oval, with the long axis parallel with the free surface. The nuclei in the most superficial layers are flattened and sometimes cannot be distinguished, having become horny with the rest of the cell.

Those who have Vol. I. of the "Studies" will find an excellent example of stratified epithelium in the V.S. human skin, taken from the sole of the foot opposite page 33. The cornea is covered by the simplest and most typical stratified epithelium. It is found on surfaces exposed to friction, viz.: the skin, lining of the mouth, part of the pharynx, the œsophagus, &c.

3. Transitional Epithelium.—This is a form between the stratified and those forms made up of a single layer. In order to procure a specimen we may distend, and tie at both ends, the ureter, taken from a recently killed dog, cat or rabbit, with chromic acid and spirit solution. Then place the ureter in a large quantity of the same solution for a few days; afterwards divide it into lengths of an inch, and complete the hardening, &c. A transverse section shews transitional epithelium well. The cells near the free surface are large and flattened with strongly marked ridges and intervening depressions; on the under surface the depressions are made by "capping" the upper part of the next lowest cells, which are pear-shaped, the stalk of the pear pointing towards the basement membrane. The pear-shaped layer dove-tails into the next lowest layer, which is irregularly spindle-shaped, and this layer again rests upon the cells which rest on the basement membrane. These lowest cells are irregularly polyhedral from super-imposed and mutual pressure.

We now draw attention to our other mode of classifying epithelia, viz. : according to function. We may tabulate them thus :—

1.—Protective.
- *a.* Stratified.
- *b.* Transitional.
- *c.* Ciliated.
- *d.* Pavement.

2.—Secretory.
- *a.* Columnar.
- *b* Spheroidal (Glandular)

We thus see that the physiology of epithelium may be regarded under two aspects :—its protective and its secretory. The first, or protective, is mechanical and sensory, thus : the stratified and the transitional protect from friction like a coat of mail, whilst the former protects by virtue of its sensory or tactile properties. Then again the cilia may be regarded as acting mechanically and carrying away noxious particles such as we find entering the air passages. The second function is secretory, which we have as yet to call vital through ignorance of the factors which produce the phenomenon.

Mode of Preparation.

A frog was taken and its small intestines, in pieces, placed in a 5 per cent. solution of ammonium chromate. The head also, with the nostrils slit up, was placed in the same. After forty-eight hours the intestines and head were washed in abundance of water, then placed in picro-carmine for a few hours. The contents of the intestines were scraped out ; the nasal septum was scraped, as also the roof of the mouth, and the scrapings mounted in Farrants' medium. We are thus enabled to show on one slide *squamous* epithelium (from the tongue), *columnar* epithelium (from the intestines), and *ciliated* epithelium (from the fauces).

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CARTILAGE.

Etymology.—From the Latin, *Cartilago.*

Description.

Cartilage is familiarly spoken of as *gristle*, and forms a most important part of the animal frame. In man and the higher animals, its use lies in its physical property, elasticity; whilst it yields to pressure instantly, it also instantly returns to its own proper form the moment pressure is removed. Its situations in the body alone denote its office; thus we find it as a framework or foundation of tubes which are called upon to bend and twist. At the same time, their passages must be held open, such as the windpipe, larynx, Eustachian tube, and external ear. Again, we find it in the nose and eyelids; whilst the chest or thorax owes much of its elasticity to the cartilages which join the free ends of the ribs to the breast-bone. Its buffer or break-shock qualities are the most strikingly shown by the hard parts of the body, the bones being "shod" with cartilage. Bones are by no means hard, rigid bodies really, but if the long bones, for instance, had not a softer material than themselves to come between at the joints, the act of walking would be impossible from the jar the movement of walking would produce. To meet this difficulty, we find the long bones expanded at their ends, and these ends are shod with cartilage. In situations where jarring is specially to be avoided, we find the approximating surfaces of the joint, themselves shod with cartilage, having a further supply in an interposed cartilaginous pad, as seen in the knee joint, also in the joint of the lower jaw, where masticulating amounting to crunching would jar the brain.

We speak of cartilage as *temporary* or *permanent:* by this we mean that the skeleton of the early embyro, which is nearly all cartilage, but which mostly becomes bone as growth proceeds, is temporary cartilage; whilst that we have described remains as a permanent structure.

Cartilage consists of two parts:

1. Cells.
2. Matrix or intercellular material.

According to the nature of the matrix, cartilage is *classed* as—

1. Hyaline cartilage.
2. Elastic cartilage.
3. Fibro-cartilage.

1. Hyaline cartilage is so called because of its matrix having a ground-glass like appearance (from *L. hyalinus*, glass). We find it at the free end of the ribs: the windpipe is composed of it, and the joint ends of bones have their opposing surfaces shod with it.

2. Elastic cartilage in the adult is hyaline cartilage permeated by elastic fibrils. The fibrils are arranged so as to form the trabeculae* of a reticulart framework; they branch and anastomose very frequently. The meshes contain fusiform groups of large nucleated *cells*, surrounded by a larger or smaller amount of hyaline cartilage substance. (Harris and Power).

3. Fibro-cartilage, or white fibro-cartilage, is found in sessamoid bones, and the approximating parts of the bones of the spinal column, intervertebral substance. Its matrix is *fibrous*, as its name indicates, and is composed of *bundles* of fibres which sometimes form lamellae, with, or without, a concentric arrangement.

Whatever the nature of the matrix, it is permeated by round, or oval, or flattened, *spaces*, called lacunae. These lacunae are formed by a distinct wall, or capsule, cohering intimately with the surrounding matrix, the two being indistinguishable, except we discover the capsule, which absorbs certain stains. The spaces each contain a cell (cartilage cell), or protoplasmic body, generally containing a single nucleus. The cell may entirely fill the space, or it may shrink away from the capsule. These cells multiply by fission, so that we often see a space with two cells in it that have arisen from fission of the one cell which the space previously contained. There are three explanations offered regarding the origin of the capsule as it appears during fission: Kölliker taught that it was an excretion by the cell it afterwards enclosed: Max Schultze regarded it as the converted superficial layer of cell protoplasm; many, however, regard it as a deposit around the cell, with whose origin the cell has had nothing to do. The arrangement of these lacunae, and their contained cells, is to be noticed also their relative sizes. Towards the free surface of a hyaline cartilage the cells and spaces are usually very much smaller than at the parts near the bone which they "cap." Again they may be more flattened, or elongated, and if so, the long axis of the elongation is to be noticed; in the cartilage of the ribs, this axis approaches, in direction, the surface, and may get quite parallel with it.

Cartilage is frequently spoken of as a non-vascular substance but this assertion must be qualified. All cartilages except those of the joints are covered by perichondrium or fibro-vascular membrane. That the constituents of cartilage (cells in a matrix) must come in contact with the blood plasma there is no doubt, therefore whatever the constitution of these channels or spaces may be which this plasma (fluid) travels along they have the carrying or transmitting functions of vessels. The ultimate particles of *any* tissue in exactly the same sense are non-vascular

**Trabs*, a beam. †*Rete*, a net.

and are bathed by the plasma which has been poured forth from the *nearest* vessel so that it is rather a question of *distance* than of vascularity or non-vascularity. The great distance of the cartilage substance from its plasma supply renders its repair when injured exceedingly tardy. A wound or gap in cartilage is first of all filled by connective tissue, which may or may not gradually transform into hyaline cartilage. When cartilage is wounded its margins are much more likely to heal than the deeper parts, in other words, the perichondrium is the main source of the healing factors.

Methods of Preparation.

Cartilage must be prepared in several ways, if we wish to see everything, as no one preparation can show all that is to be seen.

First, we ought to prepare a specimen of each kind of the tissue, by placing pieces, for 48 hours, in a saturated solution of picric acid.

1. Hyaline cartilage may be taken from the trachea, the cartilage of the rib (costal cartilage), or a slice may be taken from the cartilage capping the end of a long bone.

2. Yellow-fibre cartilage may be obtained from the epiglottis of an ox. Place bits in a saturated solution of picric acid for 48 hours, then wash away all the acid, and either cut, stain, and mount at the time, or if not convenient, place it in spirit till required.

3. White-fibro cartilage is best obtained, by cutting away an intervertebral disc, with its adherent bone; placing this in chromic and nitric fluid, until a needle can be thrust easily through the bone; then wash away all the acid, and place in spirit till required.

Hyaline cartilage, stained with logwood, shews the matrix and cells. Take a section and irrigate it with water, which causes the cell to shrink away from its capsule, and to become coarsely granular. Stain sections of costal cartilage, taken from a young kitten, in osmic acid, 1% for 12 hours. This stains the corpuscles a deeper yellow than the matrix. Osmic acid, Iodine solution, silver nitrate solutions, carmine, and eosin are all required in the study of cartilage. The cartilage must also be of fœtal age, adult age, and the cartilage of an aged human being, if possible, ought to be procured, and first, decalcified.

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FIBROUS CONNECTIVE TISSUE.

Areolar Tissue × 400 Diam.

Etymology.—Areola (dim. of area, a void space). Areolar tissue is the filmy tissue which largely pervades and connects the different parts of the organs of the body, hence its name *connective tissue.* The older writers called it cellular tissue ignoring its essentially fibrous character. It is often spoken of as the filamentous tissue.

Introduction.

Much confusion exists in speaking and writing of areolar tissue on account of the very numerous terms—many more than we have mentioned—under which it is known. It is a compound of two fibrous tissues (white fibrous and yellow elastic) enclosing cells and spaces (areolae).

Klein, in his brilliant little manual,[1] does much to clear the confusion by dividing connective tissues into "three great groups":—

1. Fibrous connective tissue.
2. Cartilage.
3. Bone.

These he points out have in common a *ground substance* or *matrix* together with, but distinguishable from, *cells.*

In fibrous connective tissue, the *matrix* yields gelatin: in cartilage it yields chondrin; and in bone it is petrified with, and therefore yields, inorganic salts. In fibrous connective tissue the cells are called *connective tissue cells* or *connective tissue corpuscles:* in cartilage the cells are called *cartilage cells:* in bone they are called *bone cells.*

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[1]Elements of Histology. Cassell & Co.

White fibrous tissue, its forms and disposal, plus its accompanying cells or corpuscles, form the greater part of the fibrous connective tissues including areolar tissue. White fibrous tissue forms rope like bodies (tendons) which connect muscles with bones. As *fasciae* (from the Latin *fascia*, a bandage) or sheet like expansions, it forms sheaths for the muscles. It forms also a felt work, by its bundles repeatedly crossing and dividing. This felt work may be close and compact, as in the dura mater and sheaths of tendons, or it may be so loose as to allow areas or void spaces (areolæ) as seen under any part of the skin. Lastly, it may form a fenestrated membrane, by its bundles interlacing *in the same plane.* We thus see that its forms and disposal may be regarded as four, namely : 1, Rope-like bodies (tendons) ; 2, Sheet-like bodies (fasciae) ; 3, Open, or close felt-work ; 4, Fenestrae.

White fibrous tissue in our drawing and accompanying slide is seen to be composed of bundles of fine fibres running strictly parallel with each other but taking a wavy course. However the bundles themselves run, whether parallel to each other, as in tendons and fasciae, or dividing and re-uniting and crossing each other as in the felt work, or fenestrated forms, the individual fibres composing the bundles *always* maintain their general parallelism to one another. Other peculiarities of these filaments are that they never divide into branches, or unite with one another. When seen by reflected light they appear white or nearly so ; they, however, readily transmit light and appear transparent. They are to all appearance homogeneous, and the same thickness throughout their course, and vary in diameter from the 50,000 to the 25,000 of an inch. The bundles formed by the filaments vary much in thickness, some being made up of very few filaments, never, however, less then three or four, whilst in others many scores may be seen. The filaments are held together by a semi-fluid albuminous *cement* which is also present between the bundles forming a trabecula. To demonstrate this, tear off a narrow strip of tendo-Achilles from any quadruped: place it in a saturated solution of picric acid for forty-eight hours: wash away all coloring matter by repeatedly changing the water : tear off a small shred and tease it well out in three-quarter per cent. salt solution, then cover and examine.

The *fibrous connective tissue cells* or *corpuscles*, vary much in shape, which largely depends on their surroundings. In tendons and fasciae they are flattened squares, or oblongs, placed end to end, situated on the surface of groups of fibre bundles. Between the ends of the cells is found the *albuminous cement.* In mucous membranes, true skin, serous membranes, cornea, and subcutaneous tissue, the cells are flattened and branched, branches of one cell joining with those of another, thus forming intercellular communication.

Yellow elastic tissue is usually associated with the white fibrous tissue in most places. When seen in bulk as in the ligamentum nucha of large quadrupeds, such as the horse, ox, &c., it is seen to be yellow in colour, but when single fibres are seen by transmitted light, as in the slide

accompanying this number, they appear transparent with a well-defined outline. We can always readily distinguish them from the white fibrous tissue, which we have seen runs in wavy parallel bundles of filaments; the fibres of yellow elastic tissue run in bold curves, and the *ends* of the fibres *curl*. Again, we saw that the white filaments never branched, the yellow fibres branch, and not only so, but the branches join and form a reticulum. When cut across, the yellow fibres are seen to be *angular*. When much white fibre is present, and very little yellow elastic, the latter is discovered by irrigating the specimen with a one per cent. solution of acetic acid in water. This causes the white fibrous tissue to swell up and become indistinct and leaves the yellow fibres alone and untouched; it also, by the way, brings the cells into view.

AREOLAR TISSUE.

By our foregoing remarks it will be seen that the practice of describing areolar tissue as a special variety of a fibrous connective tissue is misleading. It is really a typical connective fibrous tissue, made up of larger or smaller bundles of white fibrous tissue copiously mixed with yellow elastic fibres, the two blending with one another to form a felt work, usually of loose texture. The yellow fibres run in the *ground substance*, between the white bundles, and appear very often, as in our specimen, to run on the surface. The areolæ or interspaces are *clefts*, and freely communicate, being formed by the liquefaction of the ground substance and development of fibres, and are occupied by the connective tissue cells or corpuscles.

Except in the eyelids and one other part, the areolar tissue, which lies beneath the skin in all parts of the body, and is therefore called subcutaneous tissue, contains fat cells. Each cell is formed of a capsule of protoplasm, having at one part of its periphery a more or less flattened nucleus, and encloses a globule of oil. These fat cells are formed by the conversion of the original connective tissue corpuscle. When men and animals "grow fat," it is this conversion of the subcutaneous connective tissue corpuscles into fat cells which gives the body its rotundity. In starving animals the oil gets absorbed, and the fat cell diminishes, and contains only a serous fluid, which itself disappears as starvation proceeds. It is thus seen that the areolar tissue beneath the skin is the great store house of the body. The fat is stored up in it in good times, to be called upon by the body's needs in time of want.

Areolar tissue next after the blood is the most universally distributed of the tissues. As we have said, it lies beneath the skin everywhere, also beneath the serous and mucous membranes, attaching them to the parts which they cover or invest. It pervades and also invests the different organs, such as muscles, nerves, blood-vessels, lobes, and lobules of compound glands, the hollow viscera, such as the bowels, etc. It is not

only universally distributed, but is continuous with itself throughout. It is through the areolæ of this tissue that our medicines, injected beneath the skin anywhere, get into the blood instantly and over the whole system; it is in this that dropsy lodges, and freely shifts its quarters from ankles to eyelids and face, or any other part, often depending upon position only. In the days before the legal protection of animals from cruelty, the butcher whitened his veal by bleeding the calf almost to faintness a day or two before killing it, and after piercing the skin, inserted his tobacco pipe stem, and inflated the entire skin by blowing into the areolar tissue. Should a quadruped have an abscess form and discharge, or receive a cut through the skin over the breast between the fore legs, the action of the large pectoral muscles suffices to suck in air, and the entire skin is puffed up by the air being drawn into the areolæ of the subcutaneous tissue.

It is thus seen that the areolar tissue is our store-house of fat: it receives watery deposits from the blood-vessels: it acts as a convenient receptacle for medicaments, whether injected beneath the skin with a syringe, or rubbed into the skin by inunction: it enables the skin to move freely over the subjacent parts, and retracts the skin when the latter is drawn away, and makes the cut skin gape by drawing its cut edges apart, for which we do not thank it. Its other kindly (and unkindly) offices, are really "too numerous to mention."

Mode of Preparation.

For studying areolar tissue, snip out a minute piece of the subcutaneous tissue from a newly-killed quadruped: place it quickly on a dry slip, and spread it out with needles, breathing upon it from time to time to prevent it drying, then place on it normal salt solution, cover, and examine.

For a permanent specimen, inject the axilla of a newly-killed kitten or young rat, with a 1% solution of osmic acid. When a bulla has formed, snip out the areolar tissue, avoiding hairs, place it on a slip as before, and put on it a large drop of picro carmine, frequently renewed through 24 hours; then replace this with glycerine jelly and cover. Logwood may be used in place of picro carmine; also glycerine may be passed under the cover glass, instead of using the glycerine jelly.

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FIBROUS CONNECTIVE TISSUE.

(Continued.)

Tendon T.S. × diam.

Etymology.—(τένων, a tendon, from τείνω, I stretch). A fibrous cord at the extremity of a muscle by which a muscle is connected with a bone. Tendons are white and glistening, and vary in length and thickness: they are sometimes round, sometimes flattened: they are of considerable strength, with very little elasticity.

Description.

Tendons consist almost entirely of white fibrous tissue, the fibrils of which have an undulating course parallel with each other, and are firmly united together. The bundles of fibres do not keep separate throughout their length, but send slips *to* neighbouring bundles, and receive slips *from* neighbouring bundles in return; hence, successive transverse sections of the same tendon reveal different figures of the sectional areas of the bundles. On referring to the present slide, it will be observed that the bundles are not only invested by dense areolar tissue, but trabeculae are sent from this into the interior, forming septae of greater or less thickness, thus uniting all the bundles of fibres into one large collection of fibres. Besides binding the bundles together, these septae of areolar tissue serve as an imbedding and protecting agent for the vessels and nerves, which, however, are very sparingly supplied, and of small size, running for the most part in the larger trabeculae and sending communicating branches across them, and then forming an open network with large oblong meshes. If tendons seem to lack blood vessels, they at all events are richly supplied with lymphatic vessels which penetrate both the large and small trabeculae of the areolar tissue. The present slide exhibits these in numerous places transmitting light from the mirror as if they were so many pin-holes. Their areolar character is shown by their irregular outline, also by the fibres running across each at a lower level. The tendon cells are seen in section as irregularly stellate. They are stained, and give each bundle of fibres a dotted appearance, as seen with a low power such as an inch. The tendon cell consists of a protoplasmic body, thick at the centre, and thinning off into extensions, hence its stellate form. When seen in a longitudinal section of a tendon they *appear* quadrangular or oblong. As the body of the cell lies between the angular space between three or more bundles of fibres its lamellar processes extend into the interstices between these contiguous bundles. It will thus readily be seen that the oblong form of the cells as viewed from the side is quite consistent with their

being stellate when viewed in transverse section, the bodies of course are flattened as well as the extensions or processes, but not so much so. When viewed in longitudinal section, the cells are seen to form a ribbon shape, with slight interspaces between each cell, their nuclei being at the end of the cell, those of every two cells being as close together as possible. Another peculiarity of the longitudinal section of the tendon with its cells *in situ* is the appearance of the attenuated processes: these appear as well-defined dark lines, usually two in number, which are seen in the same focus as the cell nucleus.

When a muscle ends in a tendon, the muscle fibres either run in the same direction as tendon bundles, or join the tendon at an acute angle. The fibres of each tendon-bundle end abruptly on reaching the rounded or obliquely truncated extremity of a muscular fibre, and are so intimately united to the prolongation of sarcolemma, which covers the extremity, as to render the separation difficult to detect. RANVIER.

MODES OF PREPARATION.

There are four structures or elements to be observed in tendon, namely :—

Areolar tissue investment.
Ground substance or matrix.
Fibres.
Cells.
Vessels and nerves.

It is obvious that we require more preparations than one, to exhibit the peculiarities of each. For instance, we have seen that the cells, viewed lengthwise, have an oblong appearance, but, when cut across, are irregularly stellate, therefore, either a transverse section, or a longitudinal one, would, by itself, be insufficient for the cells. Two sections, and one teased preparation, are needed, to show everything that can be made out.

Ground substance or matrix.—On page 22, of the last number, this has been described, and a description of the process for seeing it.

Fibres.—The tendo achilles of a calf is taken, and an inch or so of its length cut out. This is to be again cut longitudinally into three or four pieces. Place the pieces for a fortnight in Müller's fluid, then wash away all the colouring matter by frequent changes of water, and transfer to 50, afterwards to 70 per cent., alcohol. Longitudinal sections of this cut very thin, stained in picro carmine, and mounted in Farrant's medium, will shew the fibres very well.

Cells.—Take the tail of a new-born rat or mouse, nip the end of it, and draw out a leash of tendons; place these for five minutes in filtered juice of a fresh lemon. They clear up, swell, and become transparent. Now wash them in distilled water and transfer them to one per cent. solution

of auric chloride for twenty minutes, and after they have assumed a deep yellow tint, again wash them in distilled water, and transfer them to an ounce of 25 p.c. solution of Formic Acid. Place in the dark, in a cool place, for twenty-four hours. Again wash in water. They are now purple throughout. Take a small piece of one of them, and tease it out with needles, in a drop of glycerine, and cover. The cover glass may be used in place of the needles, by squeezing and flattening out the preparation. This shews the relation of the cells and fibres.

Again, take the tail of a rat, and treat it with auric chloride, as in the last case. Now transfer it to chromic and nitric fluid to decalcify. Make transverse and longitudinal sections: stain these in Iodine green and in aniline blue—at least in the former—then mount in benzole balsam.

Areolar-tissue.—This is well seen in the transverse section of the rat's tail as above.

Vessels.—These may be injected with a carmine mass in the rat, if desired, though it is scarcely worth while, as the vessels are quite unmistakable without injection.

Relation of Muscle to Tendon.—Cut out the diaphragm of a newly-killed rabbit: place it in filtered fresh lemon juice for five minutes: then steep it in 1 p.c. aqueous solution of auric chloride for one hour, and transfer to 25 p.c. solution of Formic acid 24 hours, the preparation to be kept in a dark, cool place during the latter period. Snip out a piece of muscle with central tendon attached, and tease in glycerine. It is better perhaps to place the whole in gum and syrup (see Methods of Microscopical Research), then freeze and cut. The section is to be parallel with the long axis of the muscle fibres.

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ADIPOSE TISSUE.

× 250 diameters.

Etymology.—The word adipose is from the latin *adeps, adipis*, fat.

FATS.

These substances, like the sugars, are derived from both animal and vegetable sources. There are three principal varieties of them, which may be considered as representing the class, viz. :

Oleine - -	C_{94}	H_{87}	O_1
Margarine - -	C_{76}	H_{75}	O_{12}
Stearine - -	C_{142}	H_{141}	O_{17}

The principal difference between the oleaginous and saccharine substances, so far as regards their ultimate composition, is that in the sugars the oxygen and hydrogen always exist together in the proportion to form water; while in the fats the proportions of carbon and hydrogen are nearly the same, but that of oxygen is considerably less. The fats are all fluid at a high temperature, but assume the solid form on cooling. Their melting points vary very much, and are :—

Stearine,	143° Fahr.	
Margarine,	118°	„
Oleine,	100°	„ and less.

The fats are all insoluble in water, but readily soluble in ether. By prolonged boiling in water with a caustic alkali, they are decomposed, and as the result of the decomposition there are formed two new bodies; first, *Glycerine*, which is a colourless, neutral fluid : and, secondly, a fatty acid either oleic, margaric, or stearic, as the case may be. The glycerine remains in *a free state*, whilst the acid *unites* with the alkali to form a *soap*.

Stearine is best obtained from beef or mutton suet. It is the hardest of the fats, and crystallises in white shining plates.

Margarine (*μαργαρίς*, a pearl), or mother-of-pearl fat, is a constituent of all oils, hardening rapidly and assuming a crystalline form which glitters like mother-of-pearl.

Oleine may be obtained best from olive oil. Stearine, margarine, and oleine never occur separately: in every fatty substance they are mingled together, so that the more fluid of them hold in solution the more solid. Generally speaking, in the living body these mixtures are nearly fluid. After death, as the body cools, the stearine and margarine sometimes separate from the mixture in a crystalline form, since the oleine can no longer hold in solution so large a quantity of them as it was capable of doing during a life temperature.

In a fluid state fatty substances present themselves under the form of drops or globules, which vary greatly in size but always assume the same optical properties. They are circular in shape and have a faint amber colour, distinct in the larger globules, less so in the smaller. They have a sharp, well defined outline, and refract light strongly, and act like double convex lenses, and therefore appear with bright centres surrounded by darker borders.

Pereira gives the following per centage of oily matter in some animal and vegetable foods:—

Quantity of fat in 100 parts.

Filberts.....	60·00	Ordinary meat...	14·30
Walnuts	50·00	Liver of ox	3·89
Cocoa-nuts	47·00	Cow's milk	3·13
Olives	32·00	Human milk.....	3·55
Linseed.....	22 00	Ass's milk	0·11
Indian Corn.....	9·00	Goat's milk	3·32
Yolk of Eggs ...	28·00		

Fats or oils can easily be extracted from organised tissues by the employment of simple *mechanical* means, because the three principal varieties of oleaginous matter, though always united with each other, *are not united with the other proximate principles.* Thus, suppose we wish to extract the *sugars* of the blood, we should find them in solution in water in company with albumen, phosphate of lime, chloride of sodium, and the like in *molecular union.* On the other hand, we may remove the yolk of an egg *en masse*, churn the fat from the milks, cut animal or vegetable tissue into small pieces, and subject it to heat and pressure, and the oil is forced out and separated. The oils are found in the animal body *most abundantly* in the adipose tissue though they exist in smaller amount in the mammary gland as milk, in chyle, in the liver cells, etc. A large part of the fat, in whatever form, may be accounted for by that taken with the food, animal or vegetable, but it would seem, from the experiments of MM. Dumas and Milne-Edwards on bees,[1] M. Persoz on geese,[2] and M. Boussingault on geese, ducks, and pigs,[3] that fat is *formed* in the

[1] Annales de Chim. et de phys., 3d Series, vol. xiv., p. 400.
[2] Ibid., p. 408.
[3] Chim. Agricole, Paris, 1854.

body independently of what is introduced with the food. The observers first ascertained the quantity of fat existing in the whole body at the commencement of the experiment. The animals were then subjected to a definite nutritious regimen, in which the quantity of fatty matter was duly ascertained by analysis. The experiments lasted variously from thirty-one days to eight months, then the animals were killed and examined. The results showed that considerably more fat had accumulated in the tissues than could be accounted for by the fat of the food taken, which placed beyond doubt that the system can form fat by the metamorphosis of other proximate principles.

Although the food taken as fat, may produce most fat, other substances produce fat in abundance. In sugar-growing countries, such as Louisiana and the West Indies, during the few weeks occupied in gathering the cane and extracting the sugar, all the negroes employed on the plantation, and even the horses and cattle, that are allowed to feed freely on the saccharine juices, grow fat, and lose their superabundance of fat when the season is past.

ADIPOSE TISSUE.

As we have said, by far the greater part of the fat of the body, is enclosed in small cells or vesicles, which, together with their contained matter, constitute adipose tissue.

When seen under the microscope, the tissue is found to consist of small vesicles filled with oily matter and mostly lodged in the meshes of areolar tissue. "The vesicles are most commonly collected into little lobular clusters, and these again into the little lumps of fat which we see with the naked eye, and which in some parts are aggregated into round or irregular masses of considerable magnitude. Sometimes the vesicles, though grouped together, have less of a clustered arrangement; as when they collect alongside of the minute blood-vessels of thin membranous parts. In well nourished bodies the vesicles or fat cells are round or oval unless they are packed closely together, in which case they acquire an angular figure, and bear a striking resemblance to the cells of vegetable tissues. The greater number of them are from the $\frac{1}{100}$ to the $\frac{1}{200}$ of an inch in diamater, but may exceed or fall short of this measurement. Each one consists of a very delicate envelope enclosing the oily matter, which, completely filling the envelope, appears as a single drop. It often happens that a part of the fatty contents solidifies in the cell after death, forming a bunch of delicate needle-shaped crystals. The envelope is the remains of the original protoplasm of the cell: it is generally quite transparent, and apparently homogeneous. According to some authorities it consists of two parts: a delicate structureless external membrane, and a layer of finely granular protoplasm immediately surrounding the fat. The

nucleus is always present in the protoplasm, but is often so flattened out by the pressure of the enclosed oil-drop as to be visible only with difficulty. The areolar tissue connects and surrounds the larger lumps of fat, but forms no special envelope to the smaller clusters; and although fine fasciculi and filaments of that tissue pass irregularly over and through the clusters, yet it is probable that the vesicles are held together in these groups mainly by the fine network of capillary vessels distributed to them. In the marrow the connective tissue fibrils are but few in number or may, it is said, be absent altogether. The adipose tissue is copiously supplied with blood-vessels. The larger branches of these pass into the fat lumps, where they run between the lobules and subdivide till at length a little artery and vein are sent to each lobule, dividing into a network of capillaries, which passes between the vesicles in all directions, supporting and connecting them. The lymphatics of the fat are in close relation to the blood-vessels, accompanying and occasionally completely enclosing them as they enter the lobule. No nerves have been seen to *terminate* in this tissue, although nerves, destined to other tissues, pass through it." (QUAIN.)

METHOD OF PREPARATION.

Our section with this number is from the subcutaneous tissue of the palm of the hand. It is cut by the imbedding process, and stained with strong logwood solution and mounted in glycerine jelly.

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All works on anatomy may be consulted, as all treat on adipose tissue with greater or less lucidity. In the 9th edition of QUAIN vol. ii. p. 73, 74, 75, will be found a good description, from which we have made a large extract. Works on Physiology also have a good deal to say about the fats, etc., so have works on Chemistry.

DEVELOPMENT OF BONE.

Section × 350 diam.

Etymology.—Several terms used in discussing bone formation require to be explained or known in advance. The following words occur: the prefix oste from the Greek οστεον (a bone). Osteoblast from the Greek βλαστος (a bud, a shoot, a sucker). Osteogenetic from the Greek γενναω (to produce, to bring forth). The prefix os from the Latin os (a bone). The prefix calc from the Latin calx (lime). Diaphysis and Epiphysis are the same word with different prefixes. They are from the Greek φυω to spring forth or come into being hence διαφυω to intervene: επιφυω to grow upon, to cling closely to.

Introduction.

In order to understand the development of bone, we first propose to explain what bone is when fully formed, as we find it in the full-grown healthy animal; then we have to begin quite at the other end and trace the process from the primitive structures as we find them, not only in the fœtus but in the young or very early fœtus; thus, we count an animal's age from its birth, but before birth we count its age as a fœtus. We again have to allow for differences in fœtal development; thus a fœtus which is mature and ready to be born, so to speak, at six weeks old is mature and formed at that time and almost so at four weeks, whereas a fœtus that is only fit for a separate existence at twelve months is very imperfectly formed at four weeks. Therefore when we speak of an early fœtus or young fœtus, we must be understood to mean an early or young fœtus of the animal which bears it, and then consider how long that animal carries its young before birth.

When bone is fully formed it consists of an organic framework impregnated with lime and other earths, which make it rigid.

Lehman gives the following proportions:—

Organic matter	33 per cent.
Earthy matter	67 „

The earthy matter is almost all lime and is made up of 57 parts of the phosphate and 8 parts of the carbonate of lime: the only two remaining earthy parts are one part each of fluoride of calcium and phosphate of magnesia. Practically, then, we find bone to be made of an organic base, impregnated with lime, which has been named "bone earth." If

we soak an adult healthy bone in water, which contains one or two per cent. of hydrochloric acid, we can, in a few days, run a needle through it, without the needle encountering any resistance from grit, and if it be a long bone we can almost tie it in a knot: it still looks like a bone, however. Again, if we put an adult healthy bone in a very hot fire in a few hours we may remove it, and it still retains its shape, but is whiter. We now can pinch a piece from it, and powder the piece between our fingers: the animal basis has gone, and left the lime only. If we saw a long healthy adult bone down its middle lengthwise, we find it made up of two distinct parts: an outer compact tissue, and an inner open or cancellous tissue. These form the outer case or shaft, and enclose a hollow space, which gives it lightness and strength, because the amount of material being the same, a hollow cylinder is stronger than a solid pillar. This hollow also contains the marrow. If again, we fracture a fresh adult healthy bone, that has been cleared of its muscles and not scraped, a tough membrane will still hold the fragments together. This membrane is the periosteum, and invests the bone everywhere, except at the insertion of strong tendons, and where it is covered by cartilage. The periosteum is a tough fibrous membrane, whose chief use is as a bed in which the blood vessels divide and subdivide, until they are fine enough to enter the minute pores which are to be seen on the surface of a dried bone that has been macerated and deprived of its periosteum.

A healthy adult long bone of a mammal, such as the thigh bone of a man, horse, sheep, is anatomically divided into a shaft and two extremities. Again we find enlargements on this bone, as on other bones going under various names, such as trochanters, tuberosities, and so forth.

The parts of the embryo destined to become bone first appear in the early fœtus as a gelatinous pulp, *without a trace of organisation*, and contained in a delicate membrane. This pulp gradually *organises* and appears as hyaline cartilage, such as it is in a permanent form. This we have illustrated and described in a previous number. The entire skeleton, except the skull cap and bones of the face is first of all in the early fœtus hyaline cartilage. The bones which are to form the skull cap or cranial vault and the bones of the face are not so much as represented in the early fœtus as hyaline cartilage, but by two closely apposed delicate membranes which in the case of the cranial vault become respectively the peri-cranium and the dura-mater. *Between* these two closely apposed membranes, bone is developed. Therefore it is usual to describe bone as developed by two modes of ossification, namely :—

1. Ossification in Cartilage.
2. ,, ,, Membrane.

The former method only is exhibited by our present slide and drawing, and the very early and very late phases of this are not shewn. Those who wish to trace the process throughout can do so by the directions we shall give.

Development of Bone.

1. *Ossification in Cartilage.*—We will take the femur or thigh bone as our type. All *parts* of this or any other bone do not become ossified together, nor do all bones of the same skeleton ossify during the *same* period of time. Those bones ossify first, which are wanted first. Thus in the human being the ribs are wanted in the act of breathing, and the lower jaw is wanted in the act of sucking at birth; therefore, these are among the earliest of the fœtal skeleton to commence to ossify. On the other hand, some bones or parts of bones are not required for so long after birth that they do not commence to ossify till, in some cases, years thereafter.

The process of ossification in cartilage commences in the centre of the cartilage, therefore these spots are called *centres of ossification.* When a cartilage, forming the bone that is to be, begins to ossify, the part of it which is first to ossify has first of all a mere speck in its centre. This speck is seen to consist of minute canals for the passage of the blood vessels. Presently we see blood vessels in these canals. What are these blood-vessels doing? Blood at this early stage, as it is throughout life, is the great carting or carrying agent; it carries materials to build up the tissues through which the vessels pass, and receives from the tissues the cast off worn out material. In the present case, the blood is carrying "bone earth" in solution, to the parts, and carrying away the broken-down cartilage which the bone proper is supplanting, hence there is in the ossifying *centre* no redundancy of bulk.

The number of these centres varies in different bones, some have only one, others half-a-dozen or more, the humun sacrum has as many as thirty-three. In the human femur the first centre of ossification (that in the middle of the shaft) appears in the beginning of the third month of *fœtal* life. The second centre appears during the last month of *fœtal* life at the lower extremity which forms part of the knee. The third centre appears at the upper extremity when the *child* is a year old. In the fourth year of childhood the fourth centre forms in the large prominence (trochanter major) at the upper extremity of the bone. The fifth and last centre does not appear until the child has become a youth of fourteen or fifteen.

The shaft is the first part to ossify, *as is the case in all the long bones,* and for this reason we speak of it as the diaphysis (the part that intervenes), the other parts growing upon the shaft, so to speak, we call epiphyses. The epiphyses, during all this long period of growth, are only united to the shaft by a layer of cartilage, hence the frequency of the displacement of these epiphyses in childhood and early life of the mammal generally.

The slide and drawing ought now to be intelligible. The end of a long bone is shown. This is seen to consist of two distinct parts in the section:—

1. The end of the shaft.
2. The head of the bone.

The process of ossification commences, as we have said, in the centre of the ossifying part, and proceeds *from* the centre, in the case of the long bones, from the centre to the extremities, and in the irregular bones, or the irregular parts or epiphyses of a long bone, from the centre to the periphery. Hence in our present section we see ossification at work in two parts, first it is seen in the piece of the end of the shaft proceeding in a looped manner, the loops lying lengthwise in the long axis of the piece of the end of the shaft; second, it is seen in the centre of the half sphere or head of the bone. In both cases the fragile open network of new bone will in places have dropped out in process of cutting and mounting. The osteoblasts are stained red, and amongst these cells may be found here and there giant cells or osteoclasts. The trabeculæ are stained blue, and are calcified cartilage matrix in process of becoming covered with secondary osseous substance deposited by the osteoblasts. Being taken from an animal that uses its limbs early, the process of ossification in the shaft and head of the bone is going on synchronously. "The young lamb or foal can stand on its four legs as soon as it is born; it lifts its body well above the ground, and quickly begins to run and bound. The shock to the limbs themselves is broken and diminished at this tender age by the division of the supporting long bones, by the interposition of the cushions of cartilage between the diaphyses and the epiphyses." (Owen).

2. *Ossification of Membrane.*—For observing this a very young fœtus must be procured. Quain's Anatomy gives a figure (p. 102, fig. 100, vol. ii., Ed. ix.) of Sharpey's. It is the parietal bone of a fœtal sheep, the latter being only two and a half inches in length. The bone is about half an inch square. Should the reader desire to study ossification in membrane, a very young fœtus of a rabbit, cat, dog, or guinea pig, may be procured, stained first in carmine, then in sulph-indigotate of soda, and then cleared and mounted in balsam. He will then find a brief but clear description as above. It is obvious that a description here would be of little use without a slide or a drawing.

Mode of Preparation.

A new born puppy, kitten, guinea-pig, or rabbit is to be procured and its thigh or arm bones, or both, placed in a saturated watery solution of picric acid till a needle can be run through the bone easily and meet no grit. Then the acid is washed out with water and the bones placed in methylated spirit for a few days. Sections are then cut with a razor, the bone being imbedded in carrot. The sections are first stained in carmine, then in sulph-indigotate of soda (the process having been described in the Studies once or twice before, we need not trouble the reader with a repetition), and afterwards mounted in benzole balsam.

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Any work on Anatomy may be chosen, but the second volume of the ninth edition of Quain (Longmans & Co.) is the best.

NERVE OF HORSE.

T.S. × 150 diam.

Etymology.—*Afferent* and *efferent*, from the Latin *Fero*, I bear: *ad*, to: *ef*, from. *Neuroglia*, from the Greek *neuron*, a string, a cord, and *gloia*, glue, or *gloios*, anything sticky. *Epineurium* from *epi*, upon, etc. *Perineurium* from *peri*, around, about. *Endoneurium*, from *endon*, within, Latin *intus*. *Neurilemma* from *lemma*, a husk, a peel, a scale, something peeled off. All the latter are from the Greek.

The Nervous System.

Before describing any part of the nervous system, it may be as well to briefly describe the nervous system as a whole.

The nervous system, for descriptive purposes, may be regarded as composed of three parts, namely :—

Terminals, which receive impressions.
Transmitters, which convey these impressions.
Interpreters, which analyse and dispose of these impressions.

It will now be convenient to take these in the reverse order.

The *brain* and *spinal cord* are the great interpreting masses, but besides these there are numerous little masses called ganglia, which we may leave out of count in our description.

The *nerves* are the conveyors of impressions from the terminals or receivers to the brain and spinal cord. In other words, the nerves connect the two extremities.

The terminals vary greatly in form but are really varieties of the same thing. The agent or medium by which these terminals communicate the impressions received, and make an impression of it suitable for transference differs in each case. Take for example two of the five senses and their terminals: we have refracting media for modifying beams of light, and rendering these beams suitable for being received by the retina and transmitted by the optic nerve: we have a sound modifying apparatus for modifying sound waves before these are capable of being transmitted along the auditory nerves, and so forth. In the former case, we have an optical apparatus, and in the latter an acoustic set of apparatus, and these *instruments* of the terminals differ fundamentally.

If we disconnect the *instruments* of the terminals from the nervous system proper, we find it to be composed of two structural elements only.

1. Nerve cells.
2. Nerve fibres.

The nerve cells are much fewer in number than the fibres, for this reason: every nerve fibre commences, or terminates, in a nerve cell; but the

nerve cells are made up of a body which branches. Sometimes these branches are very numerous, and each branch is continued as a nerve fibre, or has a nerve fibre running into it. We have said the fibres commence, or terminate, in nerve cells. This leads us to remark that nerve fibres convey impressions to and from the nerve centres.

Those fibres which convey impressions *from* the end organs, or terminals, *to* the centres (brain and spinal cord) are called *afferent* or *centripetal:* those which carry the brain or spinal cord explosions or stimuli *to* the end organs, or terminals, are termed *efferent* or *centrifugal.*

By the unaided eye we can see that the nervous substance is divided into two kinds, differing in colour. These are :—

1. The white.
2. The grey, or cineritious.

The white part of the brain and spinal cord is very distinct from the grey, and is made up of nerve fibres. The grey or cineritious matter is formed largely of nerve cells. It exists on the surface of the brain and in the interior of the spinal cord.

Nerve Fibres.

We must be careful to remember the difference between nerves and nerve fibres. When we speak of a nerve, we refer to a number of nerve fibres, which run in company as a cord or nerve. It is usual to speak of two kinds of nerve fibres, the white and the grey ; but a white fibre is made up of a central axis of grey matter, which runs uninterruptedly from a cell process to its destination, and is surrounded, or coated over, with a thick white fatty coat called the *medullary sheath*, and this, again, is enclosed in a thin membrane or sheath. In other words, a *white* nerve fibre is made up of three distinct parts :—1, a central axis of grey matter ; 2, a thick white fatty sheath ; and 3, an envelope, or thin membrane, which encloses the whole. On the other hand, a *grey* nerve fibre has the central axis of grey matter almost exactly like that of the white nerve fibre, but running along, just as grey matter, and not surrounded, or coated, by anything.

Nerve Cells.

A nerve cell, like any other cell, consists of a nucleated mass of protoplasm having from one to twenty or more processes : hence we speak of uni-, bi-, or multi-polar nerve cells. The *shape* of the cell is characteristic of its locality. The round cell belongs to the spinal ganglia: the angular to the sympathetic ganglia : the irregular branching cells to the grey matter of the spinal cord : the conical to the surface of the brain : the flask or retort shape to the cerebellum, etc. The *size* of the nerve cell varies greatly. The multi-polar nerve cells in the spinal cord are so large that one can almost see them with the unaided eye, whilst those in a part of the cerebellum are so small that the layer they form is called the granular layer.

Like all other parts of the animal economy, the essential parts of the nervous system (nerve cells and fibres) require mechanical support :

require blood vessels, nerves, and lymphatics for their nourishment and continued existence during their wear and tear.

Without physical support, the delicate grey matter would be crushed or torn, especially in the large collections of nervous substance (brain and spinal cord). The physical support of the nerve cells and fibres of the brain and cord is called *neuroglia*. It consists of an extremely fine, delicate, open net-work, whose structure has not been thoroughly agreed upon. Professor Schäfer, in the second volume of Quain's anatomy, p. 149, says:— "It is not composed of cells, although these occur in it, but it is rather of the nature of an intercellular substance which occupies the interstices between the nerve fibres. The cells which are here and there found in it are flattened, and resemble small connective tissue corpuscles, and the neuroglia of the nerve centres has generally been regarded as consisting of connective tissue ground substance, especially since in many places it appears fibrillated."

Transverse Section of a Nerve.

The transverse section of a nerve, such as accompanies the present description, shows the following structure.

We have one, two, or more nerve *bundles* of different sizes, mechanically supported and held together by a fibrous arrangement of areolar tissue. The latter tissue also affords mechanical support to the nerves, arteries, veins, and lymphatics which must accompany the nerve trunk as a whole, and afford it proper nourishment.

The sheath which surrounds all the round bundles of fibres is that which we first come across in dissecting a nerve as it lies in the body, and is called epineurium. Besides this each nerve bundle has a special sheath for itself, also readily seen: this is called the neurilemma, and is *lamellar* in structure, whilst the epineurium *interlaces with itself* in all directions. The neurilemma *receives* fibres on its outer periphery from the surrounding epineurium: it also *gives off* flattened prolongations from its internal periphery, which go to form septa between the *groups* of nerve fibres which compose a single nerve bundle. From these septa again there is still a smaller structure given off, which separates the individual fibres of which a group is composed. This is called the endoneurium. This endoneurium also supports the capillary blood vessels which nourish the nerve fibres.

Modes of Preparation.

To prepare a Nerve.—Dissect out a piece of the sciatic nerve of a horse, ox, dog, or cat. The piece should be an inch long and gently stretched upon a piece of wood, or a match, and tied at both ends to prevent shrinking if taken from a small animal. If a large animal be chosen the nerve trunk must be cut lower down where it is smaller. Place the cut piece for ten days in Müller's Fluid. Then transfer to alcohol as usual. Transverse sections, stained, then cleared and mounted in balsam, shew the parts we have mentioned in their relative order.

Sections cut longitudinally should also be made. Although the nerve fibres themselves do not coalesce, the minute bundles which go to form a nerve bundle both give and receive fibres from neighbouring bundles.

To prepare a Nerve Bundle.—Take a mouse just killed: make an incision through the skin in the middle line along the breast bone, and tear away the skin right and left. Very fine lateral branches will be seen stretching from the flesh of the chest to the skin, more or less surrounded by areolar tissue. Pour over the entire parts so exposed a half per cent. solution of nitrate of silver: then after five minutes cut out little lengths of these minute nerve trunks and wash them in two or three lots of distilled water in a watch glass. After the light has changed them to a faint grey colour, mount them in glycerine jelly. We then can see the nerve fibres in the form of a bundle, and this bundle coated by a single layer of epithelium. The intercellular substance of the epithelia is darkened by the silver, and we have silver lines well defined. Here and there we see beneath this epithelial mail little crosses which we shall describe lower down.

To prepare Single Nerve Fibres.—We have seen that the medullated nerve fibres have a coat of fat over the central grey band or axis. As osmic acid blackens fat we use it to distinguish this thickest, largest part of a nerve fibre. Kill a frog and dissect out a piece of the sciatic nerve an inch long. Tie it lightly but firmly to a match with a piece of fine thread, wetting it with distilled water all the time to prevent it drying. After cutting it away place it, match and all, in a 1 per cent. solution of osmic acid for ten minutes. Remove it and wash away all the osmic acid with distilled water, then place the whole in a test tube and cover it with a solution of picro-carmine, and gently secure the end of the tube with a cork. Let it remain a fortnight (Stirling), and cut away lengths of one-eighth of an inch, and dissociate the fibres with needles by means of a dissecting microscope. After separating or isolating a few individual fibres, mount these in glycerine jelly. We now see the three components of the nerve —the axis cylinder in the centre, the large fatty (medullary) sheath stained black with the osmic acid, and the whole enveloped in a sheath. We now notice that the axis cylinder is an unbroken, continuous strand; so is the outermost sheath, but this sheath forms constrictions now and again, and in doing so constricts everything except the central axis; therefore, the fatty coat is squeezed away, so to speak, leaving the outer sheath and the central axis only to represent the nerve fibre. It is this constricted bit of sheath running *transversely*, and the central axis here seen, running, of course, *longitudinally*, which stain in the silver preparation of the mouse's nerve, and thus produce the little black crosses here and there along the course of a medullated nerve fibre.

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HUMAN CEREBELLUM.

Transverse Section × 150 diam.
(Stained with anilin blue-back.)

Etymology.—*Commissure*, Latin Committo, to unite. Cortical (cortex, bark). Encephalon, ἐν *in*, κεφαλή the head. Falx, Latin, a scythe or sickle. Fossa (from fodio to dig) a ditch or trench. Lamina a plate or layer of a flat form, which, however, may or may not be twisted upon itself. Peduncles (from pes, a foot). Pia mater, a vascular membrane investing the whole surface of the brain and spinal cord. Pinnate (pinnatus feathered). Pons (Latin pons, pontis) a bridge.

The Encephalon.

The great accumulation of nervous matter, generally termed the brain, consists of four very distinct portions, namely :—

1. The Cerebrum.
2. The Cerebellum.
3. The Pons Varolii.
4. The Medulla Oblongata.

By far the larger portion of the encephalon is the cerebrum, divided into two hemi-spheres, which extend from the forehead to the back of the head, also from one side of the head to the other. As we shall give a section and description in detail of the cerebrum in a future paper, we here omit to mention more particulars regarding it.

The cerebellum is next with regard to size, and occupies a position immediately *beneath* the hindmost third of the cerebrum. It is connected by peduncles with the remaining three portions of the encephalon, the peduncle above uniting it with the cerebrum: that below with the medulla oblongata; whilst the commissure, known as the pons Varolii, unites the two symmetrical halves which go to make the cerebellum itself.

The pons Varolii, or tuber annulare, is a thick band of nervous matter arching forward, and stretching, as we have said, between the two halves of the cerebellum. It is made up of transverse (commissural) fibres, which are pierced by longitudinal fibres passing up from the spinal cord to the cerebrum.

The medulla oblongata appears to be the uppermost part of the spinal cord, but lies within the cranium, hence it is said to be a part of the encephalon. It is wedged between the pons Varolii and the cerebellum: the former spans it and partly encloses it. It is irregularly cone shaped: the thicker part of the cone being uppermost.

"The cerebellum or hinder brain consists of two lateral hemispheres joined together by a median portion called the *worm* or *vermiform process.* This is seen on the under surface in the fossa between the hemispheres, as a well-marked projection named the inferior vermiform process, but above forms only a slight elevation, the superior vermiform process. In birds and in animals lower in the scale, this middle part of the cerebellum alone exists, and in animals it is the first part to be developed; moreover, in most mammals it forms a central lobe very distinct from the lateral portions. The hemispheres are separated behind by a deep notch. The upper vermiform process, though slightly elevated, is not marked off from the hemispheres, so that the upper surface of the organ, which is somewhat flattened in the middle and sloping downwards, at each side, is uninterrupted. Below, the hemispheres are convex, and are separated by a deep fossa named the vallicula, which is continuous with the notch behind, and in it the inferior vermiform process lies concealed in a great measure by the surrounding parts. Into this hollow the medulla oblongata is received in front, and the falx cerebelli behind. The greatest diameter of the organ is tranverse, and extends to about three and a half or four inches. Its width from before backwards is about two or two and a half inches; and its greatest depth is about two inches, but it thins out towards its lateral borders. The surface of the cerebellum is everywhere marked by deep, closely set transverse fissures which extend a considerable depth into its substance. One of these, the great horizontal fissure, divides the cerebellum into an upper and lower portion, corresponding in fact to the upper and lower surfaces, in each of which there are several lobes."

The internal arrangement of the grey and white nervous matter composing the cerebellum is well seen in the accompanying slide. The central part is composed of white nervous matter which sends out divergent and gradually thinning layers into the interior of the laminae, larger and smaller, the grey nervous matter forming everywhere the outer covering. In consequence of this arrangement of white and grey matter sections of the cerebellum *crossing* the laminae present a foliated appearance named *arbor vitae.* This appearance is seen in any vertical section, but is most conspicuous in a section which passes through the median plane, where the relative quantity of the central (white) matter is small.

The foliations are arranged somewhat pinnately, the sections of each primary lamina having those of secondary laminae clustered round it, like leaflets on a stalk. *The main branches of the white* (central) *nervous substance, or groups of them correspond with the lobules* which, though we have not mentioned it, receive names according to their shape, or appearance, or position, or fancy of the anatomists who have described them.

"The outer or grey nervous matter, also called cortical, is composed of two distinct layers, having between them at their junction a layer of cells, called the corpuscles of Purkinje. Outside the whole is the pia mater, whose blood-vessels pierce the nervous substance. The two layers are named respectively

The outer layer,
The inner layer.

The outer layer consists of a delicate matrix, containing cells and fibres. Most of the *fibres* have a direction *at right angles* to the surface; the greater number of them are the processes of the large (Purkinje's) cells. The *cells* of this outer layer are granule-like bodies, some very small, and belonging, probably, to the matrix, others somewhat larger, and probably nervous, with processes extending from one or more sides. Some of the corpuscles are connected with the processes of the large cells of Purkinje. The inner part of the layer, contiguous to the cells of Purkinje, contains nerve fibres running *parallel* to the surface.

The inner layer, that next the medullary centre, consists of granule-like corpuscles, imbedded as close groups in a gelatinous matrix, which contains also a plexus of fine nerve fibres. The corpuscles of Purkinje dip into and are, therefore, almost surrounded by these granule-like corpuscles.

The corpuscles of Purkinje lie, as we have said, between the outer and inner layers of the grey cortex. They are mostly flask-shaped, with their longer axis at right angles to the surface. Processes extend from them into both the inner and outer layers; the outer processes being by far the larger and more conspicuous, branching and dividing as they approach the surface. The inner process, after passing into the granular layer, becomes the axis cylinder of a nerve fibre, therefore it is fine and undivided.

The white (central) nervous centre of each lamina consists of nerve fibres arranged in parallel or interlacing bundles, which pass from the central or white matter of the hemispheres, etc., and appear to turn obliquely into the cortical grey substance. These disappear in the granule layer and are believed to be continuous with the axis-cylinder processes of the corpuscles of Purkinje, but some anatomists are of opinion that they arise in part by the union of the fine fibres of a plexus in the outer layer."

Mode of Preparation.

The cerebellum of a human being, cat, dog, or rabbit may be taken and cut into pieces half an inch square. These pieces are then to rest on cotton wool on the bottom of a jar filled with three parts of Müller's fluid and one of common alcohol freshly mixed, but allowed to cool before use. Keep in a cool place during hardening. Renew the fluid in twenty-four hours, then in seven days. The pieces should be left about twenty-one days in this mixture altogether. They are then to be transferred to a large quantity of a 2 per cent. solution of bichromate of ammonia for another fourteen days to complete the hardening. Now wash away all the preserving fluid by repeated changes of clean cold water and transfer to common alcohol.

Sections are to be made *across* the folia or leaflets either by freezing or imbedding. The latter is preferable if very thin sections are required, because if freezing be employed the leaflets are apt to fall asunder, and the pia mater also gets torn away. The sections are then to be stained in an alcoholic solution of anilin blue-black made as follows :—

Take of

Anilin blue-black 1 decigram.
Distilled Water, 4 c.c.
Rectified Spirit, 100 c.c.

Dissolve the dye in the water thoroughly, then add the spirit and filter. This is to be kept in a well-stoppered bottle till required.

The sections are to be stained in the above, then cleared and mounted in balsam in the ordinary way.

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We have largely used Quain's Anatomy, Vol. ii. in the above description, where a full account will be found, accompanied by excellent wood-cuts. Klein's elementary histology (Cassell and Co.) also contains a clear, concise account.

HUMAN CEREBRUM.

Vertical Section of the Grey Matter of a Cerebral Convolution
T.S. × 150 diam.

Etymology.—Arachnoid (ἀράχνη, a spider's web, εἶδος, like) Arcuate (arcus, a bow). Corpus callosum (corpus, a body and callus, hard). Dura mater (mater, mother; durus, hard).

General Description.

The largest part of the human encephalon is called the cerebrum, and extends from the fore-head to the back of the head, also from one side of the head to the other; the depth—roughly speaking—is from the top of the head to a line drawn round the head through the eyes across the temples and through half the ear-lobes, which would become a complete band meeting high up on the neck. In other words the cerebrum is the brain as seen from the outside, so to speak.

The cerebrum is composed of two hemetrical halves which nearly touch. The two halves together form an ovoid mass flattened on its under surface, having the front end the small and the larger end behind. The two halves, though nearly touching throughout their course, are separated by a very deep cleft called the longitudinal fissure. Each cerebral hemisphere, therefore, has three surfaces: a *convex* surface in contact with the cranial vault, a *flat* surface which helps to form the longitudinal fissure, and an *irregular* under surface which mostly lies on the floor of the cranial vault.

The two large hemispherical masses we call the cerebrum are separated, as we have said, by the longitudinal fissure, but in the middle this fissure is not complete. A large transverse mass of white brain-substance links the two cerebral hemispheres together. This transverse mass of white brain substance is called the *corpus callosum* or great commissure.

The surface of the hemispheres forms an arch corresponding to the top of the head; the outer portion of the cerebrum or surface is not smooth like an egg, but is composed of eminences called *convolutions*, and depressions called *sulci*. Besides the ordinary *sulci* there are deeper

ones called furrows, which divide each half of the cerebral mass into *six lobes*. These lobes from their position or function are called—

1.—Frontal.
2.—Parietal.
3.—Occipital.
4.—Temporal.
5.—Central.
6.—Olfactory.

At the present day it is of the first importance for a doctor to be able to define pretty accurately the boundaries of these lobes. For our present purpose, we may say roughly that the frontal lobe occupies the front or fore-head; the occipital lobe occupies the back of the head; and the parietal lobe the intermediate space, and so forth. The reason the lobes are so important will be described presently.

The interior of the cerebrum is studied by paring away successive layers horizontally. The first cut displays the internal *white* matter of each hemisphere, surrounded on all sides by the *grey* matter. This is called *centrum ovale minus*. A second section on the same level as the top of the *corpus callosum* discloses a still greater area of *white* matter called *centrum ovale majus*. We now see that the white matter of the hemispheres is connected by the *corpus callosum* itself *white* matter. A third layer removed discloses the hollow space in each hemisphere called the *lateral ventricles*. On the floor of each ventricle are several structures: the most noted being the two large masses of *grey* matter, the greater part of each being imbedded in the *white* substance of the hemisphere in which it lies. These large ovoid masses are called the *corpora striata* or *ganglia* of the *cerebral hemispheres*.

The brain and spinal cord being continuous structures are covered by continuous membranes, three in number:—

1.—The dura mater.
2.—The arachnoid.
3.—The pia mater.

The dura mater is a very strong, dense, inelastic, fibrous tunic, which adheres closely to the inner surface of the bones of the skull and forms their internal periosteum, the adhesion being more intimate opposite the sutures, but within the vertebral canal, *i.e.*, as it surrounds the spinal cord it forms a *loose* sheath. The dura mater within the skull is doubled upon itself and thus is enabled to leave the bones and return to them at the same place. Such a duplication is called a process. There are three such processes or partitions, namely:—one running lengthwise from the forehead to the back of the head in the middle line, which dips down and separates the two hemispheres of the cerebrum: a second has a horizontal direction, stretching *across* the back part of the skull between the cerebrum and cerebellum: and a third which, like the first, is vertical, and separates the two hemispheres of the cerebellum. By means of the dura mater, therefore, the four large masses (2 cerebral, 2 cerebellar hemispheres) which form the brain, practically, are partitioned off, and enclosed with much firmness, *but without pressure*.

The arachnoid membrane invests the brain and cord closely, but does not dip into the *sulci*. It is a delicate membrane, consisting of fine fibrous tissue bundles interlacing with each other. The intervals between the spaces are filled up by delicate membranes, composed of expanded cells.

The pia mater is a delicate highly vascular membrane, closely enveloping the surface of the convolutions and dipping into the sulci of the cerebrum. From its inner surface numerous minute blood vessels penetrate the brain substance. The same also obtains in the case of the cerebellum. Around the cord the pia mater is thicker, firmer, and paler (from being less vascular) and more adherent to the nervous matter of the cord.

It will be seen then that the membranes of the brain and cord have three distinct offices:—the dura mater mechanically supports; the arachnoid secretes serous fluid, which also acts as a packing agent; and the pia mater supplies the means of life.

The Cortical or Grey Matter.

Our section and drawing give a representation of the grey or cortical matter which caps the convolutions and dips into the sulci of the cerebrum. It contains cells and fibres embedded in neuroglia, with numerous blood vessels which pass vertically inwards.

The cells of this cortex are arranged in layers; the most external layer is narrow and forms about the $\frac{1}{10}$th of the whole thickness of the grey cortex. It is composed chiefly of neuroglia and contains a few small cells with fine processes, probably not of nervous character. A few medullated nerve-fibres occur in it forming a thin superficial white stratum immediately underneath the pia mater. The next layer of nearly the same thickness is characterised by containing a large number of small nerve cells mostly pyramidal with branching processes. The third layer is of paler tint and much greater thickness. It contains pyramidal branching cells, large and small, arranged as above described, with the pointed extremities towards the surface of the convolutions, and separated into groups by the bundles of radiating nerve fibres. The inner portion of the layer, in which the cells are larger and the separation into groups more distinct, is sometimes described as a separate layer. The fourth layer is narrower, and contains many small irregularly shaped corpuscles, round or angular, with fine processes placed irregularly and less distinctly separated into groups. The fifth layer, of greater width than the last, and blending more or less with it, is composed of fusiform and irregular cells. The fusiform corpuscles have a definite arrangement, being placed for the most part vertically at the summit of a convolution, but in the sulci, parallel to the surface, where they correspond in direction to the arcuate fibres passing from one convolution to another; they are said to be connected with these fibres. Beneath the last layer is the medullary centre with which it gradually blends.

The cells are of various forms and sizes, many of them have numerous processes. Some of these branching cells are irregular in form and position, but the majority are more regularly pyramidal in shape, with the apex of the pyramid turned towards the surface of the convolution. The average size of the larger pyramidal cells is the $\frac{1}{1800}$inch in diameter at the base, and each has a rounded nucleus having an average diameter of a $\frac{1}{2500}$inch. They generally contain a little yellowish pigment. The cells often appear to lie in distinct cavities in the grey matter, but it is uncertain if these are natural or produced by shrinking after death. The process from the apex of each cell may be traced for some distance towards the surface of the convolution, giving off one or two branches as it passes outwards. The undivided axis-cylinder process probably arises from the centre of the base of the cell. The processes of these cells, as well as the body of the cell itself, possess a distinct longitudinal striation. The smaller angular corpuscles are also provided with branches which run in various directions and probably unite into a fine network. Rounded cells, having no visible processes, also occur.

The fibres radiate from the white centre of each convolution in all directions into the grey cortex having a course for the most part perpendicular to the surface. In passing through the grey substance they are arranged in bundles about the $\frac{1}{1500}$ inch in diameter, and thus separate the nerve cells into elongated groups and give the section a columnar appearance.

Mode of Preparation.

If possible, we ought to obtain a portion of human cerebrum, and choose a frontal convolution.

It is to be prepared like the cerebellum, as described in the last histological number, and stained with aniline blue black, and mounted in Benzole Balsam.

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The second volume of Quain's Anatomy—from which we have largely quoted—contains a very concise description, explained also by the use of excellent woodcuts.

If the reader wishes to know how very important a matter it is to know the exact locality of the various convolutions, he should procure Ferrier's work on the Brain (Macmillan and Co.) Ferrier has found by applying the interrupted current to certain given areas on the convolutions of the brains of dogs and monkeys, that he can cause the movements of various sets of muscles to a certainty thus:—By applying the current to one area he causes the hind leg to advance as in walking; to another given area, the tail is wagged; to another, the shoulder is elevated; to another, the lip is elevated, and the nostril dilated; also numerous other combined muscular movements, can be produced with precision and certainty. When spiculæ of bone or matter press on these known areas, that area the surgeon determines by the results produced; he trephines, and is able thus to relieve it of the offending substance, which would cause death if allowed to remain. This terrible knowledge has been obtained by taking away the skull-cap of numerous dogs and monkeys, and as it has been the means of saving numerous human lives, and will doubtless restore to his family many a human bread-winner in the future.